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ABSTRACT

The development of selected science process skills in required and elective science classes in three high schools of a suburban Oregon school district was investigated. Science process skill knowledge in the areas of classifying, observing, interpreting data, identifying variables, modeling, and measuring was assessed by administration of an investigator-developed Science Process Competency Test (SPCT), a 24-item, multiple-choice test consisting of six subtests, one for each of the science process skill areas being assessed. In addition, other program and learner variables important in accounting for variance on the SPCT were identified. Subjects (N=900 grade 9-12 students) completed the SPCT, questionnaires, and California Achievements Tests (reading, language, mathematics) as a measure of academic achievement. The most important variable in accounting for SPCT variance was the level of academic achievement, with mathematics and reading achievement the strongest predictors. Other significant predictor variables included SPCT pretest score, sex, completing elective science, amount of elective science, elective physical science, type of required science, and school. Additional results are reported and implications/recommendations discussed. Supporting documentation (school district information, course statements, teacher materials/questionnaires, validation panel, SPCT, student materials/questionnaires, variable list, and a short essay on unified science education) are included in appendices. (Author/JN)

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THE EFFECTS OF TYPE OF CLASSROOM SCIENCE, GRADE LEVEL, YEARS WITHOUT SCIENCE INSTRUCTION, AND ELECTIVE SCIENCE COURSES ON PERFORMANCE LEVEL FOR SELECTED HIGH SCHOOL SCIENCE PROCESS SKILL COMPETENCIES

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By

David Charles Cox, Ph.D.

The Ohio State University, 1982

Professor Robert W. Howe, Adviser

The purpose of this study was to investigate the development of selected science process skills in required and elective science classes in the three high schools of a suburban Oregon school district. The subjects were 900 students in grades 9 through 12.

Data were gathered during the 1981-82 school year by the use of a Science Process Competency Test (SPCT) developed for the study and questionnaires. Previously administered California Achievement Tests scores were used as a measure of academic achievement. Students in required science classes were pretested and posttested over the school year with the SPCT. All other students were posttested only. The science process skills studied were classifying, identifying variables, interpreting data, measuring, modeling, and observing.

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Data were analyzed by means of correlation, multiple regression, analysis of variance, analysis of covariance, t-test, and effect size.

The most important variable in accounting for SPCT variance was the level of academic achievement, with mathematics and reading achievement the strongest predictors. The percentage of variance accounted for by mathematics achievement ranged from 41.70 to 47.90 percent when it was the most important predictor variable (10 cases); reading achievement accounted for 32.98 to 52.00 percent of the variance when it was the most important predictor variable (3 cases). Other significant ($p < .05$) variables included SPCT pretest score, sex, completing elective science, the amount of elective science, elective physical science courses, type of required science, and school.

Tenth-grade students had significantly ($p < .001$) higher adjusted SPCT posttest scores than ninth-grade students in required science classes. Science process skill knowledge was retained through the high school years. There were no significant ($p < .05$) differences between the adjusted SPCT scores of students who had elected no science after the required year and were one, two, or three years removed from required science. Students who had elected one or more years of science had significantly ($p < .02$) higher adjusted SPCT posttest scores than those students who had not elected science. Effect sizes for required science courses ranged from 0.27 to 0.90. The largest effect sizes were found in physical science and unified science.

THE EFFECTS OF TYPE OF CLASSROOM SCIENCE, GRADE LEVEL, YEARS WITHOUT SCIENCE INSTRUCTION, AND ELECTIVE SCIENCE COURSES ON PERFORMANCE LEVEL FOR SELECTED HIGH SCHOOL SCIENCE PROCESS SKILL COMPETENCIES

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

David Charles Cox, B.S., M.S.

* * * * *

The Ohio State University

1982

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David Charles Cox
1982

This dissertation is
dedicated to my
wife, Wilma.

ACKNOWLEDGMENTS

The completion of this study was dependent upon the participation and cooperation of hundreds of people, each one of whom deserve special mention and public acknowledgment. Unfortunately, such a lengthy undertaking would by its shear bulk discourage readers and thereby diminish the opportunity for the desired recognition. In lieu of that approach, I will for the most part acknowledge the participation, cooperation, and assistance of groups of people. However, I will adknowledge individually those people who have made contributions requiring considerable time and effort beyond their usual responsibilities. In either case, my heartfelt gratitude goes to all who played a role in helping this study become a reality.

I would first like to thank the administration of the North Clackamas School District for granting me a sabbatical leave for purposes of completing this study and giving me permission to conduct the investigation within the high schools of the school district.

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The data processing personnel within the school district were extremely generous with their expertise and equipment. Special thanks also goes to Mrs. Felicia Cronk for her assistance with the keypunching of the data.

Part of the agreement involved in the conduct of the study was to guarantee the anonymity of the teachers and students who participated. Even though I am not able to acknowledge them by name, I certainly want to express appreciation to each of the high school Science Department Coordinators and science teachers who participated. The Science Department Coordinators played a vital role in test scheduling and facilitating the flow of information between the investigator and the instructional staffs. The 12 first-level science teachers could not have been more cooperative and helpful. They enthusiastically administered the pretest and posttest to their classes, supervised the completion of several student questionnaires, completed questionnaires themselves, cooperated fully in a somewhat hectic make-up testing arrangement, and handled all testing materials and student answer sheets without any losses.

My special thanks also go out to the high school students of the North Clackamas School District. They exhibited a level of interest in the study and spirit of cooperation in the testing and data gathering that belies their age.

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My reading committee, composed of Dr. Stanley Helgeson, Dr. John Disinger, and Dr. Victor Showalter, deserve acknowledgment for time and contributions well beyond those required. They contributed in numerous and helpful ways to the general and specific formulation of both the study and the dissertation. Their ongoing commitment, high level of enthusiasm, and encouragement played an irreplaceable role in the evolution of this dissertation from initial ideas to final form.

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CHAPTER I

INTRODUCTION

The Science Process Skills

From the latter portion of the 1950's through the present, there has been a significant movement to incorporate more inquiry and investigative experience into school science education. The desired learning outcomes associated with this approach typically manifest themselves in the form of intellectual skills referred to collectively as the science process skills. In an instructional frame of reference, "the processes are intellectual skills which students use in the classroom as they collect and interpret data (Tobin and Capie 1980, p. 590)."

Perhaps the most definitive analysis to date of these particular types of intellectual skills is that prepared for the Commission on Science Education of the American Association for the Advancement of Science (AAAS) as a part of its development of a kindergarten through grade six science program known as Science--A Process Approach (S--APA). Eight science process skills were identified as "basic"; they are observing, using space/time relationships, classifying, using numbers, measuring, communicating, predicting, and inferring. An additional five process skills, each more complex and operationally subsuming of the previously listed basic skills, are categorized as the "integrated" science process skills. These integrated skills are controlling variables, interpreting data, formulating hypotheses, defining operationally, and experimenting (Commission on Science Education of the AAAS 1970).

Other science educators have expanded and/or modified the list of science process skills generated by the AAAS. One such effort (Showalter et al. 1974) added the processes of questioning and formulating models, the latter of which had been dropped by the AAAS Commission on Science Education during the development of S--APA. Nay (1981) has developed an inventory of processes in scientific inquiry that groups an expanded number of process skills into five categories. These categories are initiation, collection of data, processing data, conceptualization of data, and open-endedness.

These intellectual processes of science have now attained acceptance as legitimate science "content" for instruction, and many educators have described the development of science process skills as a major objective of science education (e.g., Hurd and Gallagher 1968; Renner and Stafford 1972; Okey 1972; Aikenhead 1979). Atwood (1974, p. 70) when examining science teacher education stated, " . . . processes of science are generally receiving considerable attention at all levels. The profession's wide acceptance of the process goals is one of its most outstanding achievements of the last decade."

Competency-Based Science Education

A concomitant educational movement that gained much momentum in the 1970's stressed the curriculum approach known as competency-based education. In competency-based education, classroom learning activities are designed to enable participating learners to develop competency in carefully defined areas of knowledge, skill, and/or understanding. Often, a minimum acceptable level of student performance is specified for each competency. Typically, the quality of the instructional program is judged primarily on the basis of the percentage of students able to demonstrate acceptable performance on a given set of competencies at the completion of the planned instruction.

The use of this approach in science education has received professional endorsement (e.g., Steiner 1975), and some large educational units have implemented all or part of the strategy. Among these units are the District of Columbia Public Schools (Dept. of Research and Evaluation of the District of Columbia Public Schools 1979) and the School District of Philadelphia (Kelner and Hofkin 1980; Melton 1978). In the west, the State of Oregon mandated that its local school districts specify competency-based high school graduation requirements (Oregon Dept. of Education 1976).

The Research Focus

There are instances where the two previously discussed movements, the desire for science process skill learning outcomes and competency-based science education, have merged in the classroom setting. Here it is not unusual to find science process skills designated as competencies in science classes. The study reported here was conducted in one of these operational interfaces at the high school level in an Oregon school district.

While a substantial volume of research has investigated student science process skill development and related instruction at the elementary level, surprisingly little has been reported at the high school level. For purposes of this study, high school level refers to grades 9 through 12. In the work that has been published, there appears to be a rather major emphasis on investigating various aspects of the individual learner and how these characteristics relate to science process skill development. One such study, for example, looked for a relationship between student cognitive preferences for memorizing, questioning, or applying and process skill achievement in ninth-grade science (Atwood and Stevens 1978). Other high school learner variables studied in relation to process skill performance levels include sex, age, grade level, number of completed science courses, and interest in science careers (Pettus and Haley 1980).

Another small group of studies have examined some specific instructional strategies (e.g., Biological Sciences Curriculum Study Invitations to Enquiry, Biological Sciences Curriculum Study Single Topic Inquiry Films) and attempted to assess their impact on science process skill development. Examples of these types of studies are those of Starr (1970) and Castelli (1970).

A limited collection of studies have examined the effectiveness of either a single course in promoting the development of process skills (e.g., Aikenhead 1980; Seymour and Sutman 1973) or conducted a controlled comparison to determine the relative effectiveness of two different courses. Representative of this latter type would be the work reported by McCann (1968).

This study complements and extends the various studies conducted to date as it focuses upon the effects of four different types of first-experienced high school science, the grade level at which that science is experienced, and the impact of elective science courses on science process skill performance level. In addition, the stability of science process skill performance level is examined through time.

The Problem

School districts that require only one year of high school science and specify high school level competencies, goals, or objectives encompassing the science process skills are faced with a number of important questions. Among these critical questions are the following:

1. Does the type of science that serves as the basis of the classroom learning experiences during the required year of science have any significant relationship to the process skill competency performance level achieved by students?

2. Does the grade level where science is last required have a significant relationship to the student performance level attained on science process skill competencies?

3. What science process skill competency performance levels do students have one, two, or three years after the last required science course has been completed?

4. Do elective science courses completed after the last required year of science have a significant relationship to the level of performance on science process skill competencies?

5. What student and science program variables account for the variance related to posttest measurement of science process skill competency performance level?

The answers to these questions represent crucial elements of the decision-making information base for school personnel whose responsibility it is to see that instructional programs are designed and implemented in such a manner that learners are provided with the best possible set of timely experiences commensurate with desired program outcomes. Little formal research has been conducted to suggest answers to these types of questions. However, questions raised in the study by Pettus and Haley (1980) further support the need for research in this area. Their study suggests that " . . . , the fact that the number of science courses completed appeared directly related to proficiency on the science process skills indicated that science instruction, including the amount and possibly the type, may have been important in developing the skills." (Pettus and Haley 1980, p. 276). This study addressed both of these issues.

The Research Environment

A particularly rich environment in which to conduct research related to the questions enumerated in the prior section is one where educational decision-makers have a desire for answers to such questions and programs using science process skill competencies have already been implemented. This combination of desirable characteristics exists in the State of Oregon, where the entire state moved in 1976 into goal-based educational planning with locally specified competencies for graduation. Student competency in the use of basic scientific and technological processes was required by the Oregon Department of Education (1976).

In a 1976 survey conducted to identify educational needs in the Pacific Northwest, science rated 5th of 18 curriculum areas needing improvement or expansion. On the same survey, competency-based instruction rated 5th of 16 instructional methods needing improvement or expansion. In Oregon, science and competency-based instruction both ranked third on the list of priority items (Northwest Regional Educational Laboratory 1976).

The most recent Pacific Northwest needs survey was conducted in 1980; science rated 9th of 16 curriculum areas in terms of likely future emphasis. Competency-based instruction rated 6th of 18 instructional areas relative to desired emphasis. It is interesting to note that the priority for emphasis on competency-based instruction had remained in the top one-third of the list over the four-year period. Interest in improvement and/or expansion of science instruction remained in the top half of the list over the same period of time. In the most recent survey, program evaluation emerged with the highest priority rating of 19 policy, administration, and management area needs (Bridges and Olson 1980). This study addressed all three of these high priority concerns.

While the State of Oregon no longer requires the specification of minimum competencies in the use of basic scientific and technological processes, there remain school districts who do have minimum competencies in the science process skills and instructional programs designed to enable learners to achieve those competencies. This study was conducted in one of those school districts.

Delimitations

The study is restricted as follows:

1. Data were gathered in the three high schools of a single Oregon school district

2. Student performance level was measured on six of the eight science process skill minimum competencies developed and adopted by the local school district; the two excluded process skill minimum competencies were not amenable to valid measurement with the type of instrument used in the study

3. Only students enrolled in the required year of science were both pretested and posttested

4. With the exception of formal mathematics instruction, the possible impact of other non-science formal instruction within the school was not assessed

5. The impact of nonformal instruction was not measured

6. The types of science students were enrolled in for the required year were limited to biology, earth and space science, physical science, and unified science

7. Individual learner characteristics such as cognitive preferences, attitude toward science, perception of teaching strategies, critical thinking skills, verbal predictive ability, career aspirations, cultural differences, classroom locus of control, grade point average, degree of engagement with the learning activities, and stage of cognitive development were not measured or assessed

8. Individual teacher characteristics such as attitude toward teaching, understanding of science, teaching strategy preferences, and science process skill competency were not measured or assessed

9. No investigator influence or control was used relative to staff or student assignments, schedules, or related school instructional organization matters

Assumptions

The assumptions associated with the research are as follows:

1. Completion of pretesting and posttesting of the students enrolled in the required science classes of the individual high schools over a maximum interval of six days did not produce a difference in scores

2. Minor differences in test administration within and between the individual high schools did not produce a difference in scores

3. The investigator-developed Science Process Competency Test (SPCT) provided a reliable and valid measurement of science process skill performance level

4. Students made honest efforts to successfully respond to each item on the test instrument, thereby producing representative sample data

Limitations

The limitations of the study are as follows:

1. The results of the study are only reliably generalizable to the school district in which it was conducted

2. The science process skill time on task in the various required science classes was not controlled

3. The individual high schools and their overall environmental context may have had an impact on the measured variance that was not detected

Null Hypotheses

The null hypotheses tested are as follows:

1. Academic ability is not a significant variable in accounting for SPCT posttest variance as measured by

a) Reading achievement

b) Language achievement

c) Mathematics achievement

2. Sex is not a significant variable in accounting for SPCT posttest variance

3. Type of science is not a significant variable in accounting for SPCT posttest variance

4. There is no significant difference between the adjusted SPCT posttest means of ninth-grade and tenth-grade students

5. There is no significant difference between the adjusted SPCT posttest means of students who have elected no science after the required year and are one, two, or three years removed from required science

6. There is no significant difference between the adjusted SPCT posttest means of those students who have elected science after the required year and are one, two, or three years removed from required science

7. There is no significant difference between the adjusted SPCT posttest means of students who have elected science after the required year and students who have not elected science after the required year.

8. There is no significant difference between the adjusted SPCT posttest means of students who elected science after the required year and students in the same grade level who did not elect science after the required year

9. There is no significant difference between the SPCT pretest/posttest effect size for the different types of science

Definitions

For purposes of this study, key words and phrases are defined as follows:

1. Classifying (science process skill)--"systematically imposing order on data (Oregon Department of Education 1979, p. 4)"

2. Communicating (science process skill)--"exchanging information (Oregon Department of Education 1979, p. 4)"

3. Competency(ies)--"a statement(s) of desired student performance representing demonstrable ability to apply knowledge, understanding, and/or skills assumed to contribute to success in life role functions (Oregon Department of Education 1976, p. 5)"

4. Dependent variable--student performance level on the North Clackamas School District's minimum competencies in scientific/technological processes

5. First-level science courses--the first available non-prerequisite high school science courses that will fulfill the one year of laboratory science graduation requirement (e.g., Biology 1-2, Earth and Space Science 1-2, Physical Science 1-2, Science 1-2)

6. Recognizing variables (science process skill)--identifying factors that may influence observations during an experiment

7. Independent variables--the independent variables directly associated with the null hypotheses are academic ability (reading, language, and mathematics), sex, type of science (biology, earth and space, physical, and unified), grade level (nine and ten),

number of years of high school science elected beyond the required year, years without science instruction after completion of the required year of science and effect size (A complete list of the independent variables included in the study can be found in appendix G.)

8. Inferring (science process skill)--"concluding from known facts or evidence (Oregon Department of Education 1979, p. 4)"

9. Interpreting data (science process skill)--"finding patterns or meanings not immediately apparent (Oregon Department of Education 1979, p. 4)"

10. Measuring (science process skill)--"using instruments to determine value (Oregon Department of Education 1979, p. 4)"

11. Minimum competency(ies)--competency(ies) that must be demonstrated in order to fulfill one component of the high school graduation requirements

12. Model (scientific)--"a representation having explanatory value (Oregon Department of Education 1979, p. 4)"

13. Observing (science process skill)--"using the senses to obtain information (Oregon Department of Education 1979, p. 4)"

14. Predicting (science process skill)--"foretelling from previous information (Oregon Department of Education 1979, p. 4)"

15. Regular students--English speaking high school students who were enrolled in the usual domain of courses for their grade level

16. Sample One--Regular students enrolled in first-level science courses during grade nine or ten and fulfilling their high school graduation requirement in science

17. Sample Two--a random sample of regular students who have previously completed their required high school science

18. School district minimum competencies in scientific/ technological processes--

". . . 1 The student is able to fit an organism, object, or substance into a scientific classification scheme.

". . . 2 The student is able to make laboratory observations and make inferences from these observations.

". . . 3 The student is able to communicate scientific concepts and ideas with the teacher and fellow students.

". . . 4 The student is able to interpret data and make predictions from these interpretations.

". . . 5 The student is able to recognize variables and predict what would happen when selected variables are altered.

". . . 6 The student is able to set up and complete an experiment.

". . . 7 The student is able to recognize and use scientific models.

". . . 8 The student is able to demonstrate a knowledge of the metric [system] and use common measuring instruments (North Clackamas School District No. 12 1975, p. [10])."

19. Science process skills--those intellectual skills used in collecting and analyzing data for purposes such as explaining phenomena, testing hypotheses, solving problems, and validating models

Overview

Data for purposes of assessing science process skill competency performance level were collected during the 1981-82 school year from samples of students enrolled in grades 9 through 12 of the three comprehensive high schools of Oregon's North Clackamas School District. Sample One, from the population of students in grades nine and ten who were enrolled in required first-level science courses, underwent September pretesting and May posttesting with the SPCT. The SPCT was developed by the investigator for purposes of assessing student performance level relative to six of the eight science process skill competencies required for graduation from the North Clackamas School District. The various first-level science courses that will fulfill Oregon's one-year laboratory science graduation requirement and provide the opportunity for demonstration of required school district science process skill competencies are summarized in table 1.

TABLE 1

FIRST-LEVEL SCIENCE COURSES IN THE HIGH SCHOOLS OF THE NORTH CLACKAMAS SCHOOL DISTRICT

School	Science Required	First-Level Science Course(s)
Clackamas	Grade 10	Biology Physical Science
Milwaukie	Grade 9	Biology Earth and Space Science Integrated Science (Unified Science)
Rex Putnam	Grade 10	Science (Unified Science)

Sample Two, which was comprised of randomly selected students from grades 10 through 12, experienced only May posttesting with the SPCT. The scholastic ability of students in both samples was assessed by the use of student scores on school district administered California Achievement Tests (CAT).

Statistical procedures used in interpreting the data and testing the hypotheses included correlation, t-test, multiple regression, analysis of variance, and analysis of covariance. When testing hypotheses, differences at the 0.05 level were considered significant.

CHAPTER II

REVIEW OF THE RELATED LITERATURE

Introduction

This chapter reviews the science education literature related to the study. Sections are devoted to the emergence of the science process skills as valued learning outcomes for science education, research related to the science process skills, research related to school science achievement, research related to reading and science testing, and the relation of this study to the literature. For the most part, the literature cited has been restricted to that applicable to the high school (grades 9 through 12) level.

Science Process Skills in the Curriculum

The science process skills, as they are defined in the contemporary science education community, have not always been viewed as independently legitimate "content" or high priority learning outcomes for science instruction at the high school level. In the pre-1900 equivalent of today's American high schools, science instruction, when present, focused primarily upon the aims of acquisition of scientific knowledge and arousal of interest. Only a small percentage of the somewhat encyclopedic texts, perhaps ten percent, mentioned the development of scientific thinking and observing as major aims (Nietz 1966).

The amount of instructional time devoted to laboratory work, however, had increased rather dramatically by the turn of the century, as the science curriculum and corresponding learning materials began to sever their European ties and evolve their American character. It should be kept in mind, however, that other than the identification exercises such as those in botany, the major intent of laboratory work was to illustrate principles rather than develop investigative skills in students. In fact, many of the activities labeled experiments may well have been conducted by teachers as demonstrations (Nietz 1966). John Dewey rather succinctly summarized the general state of science education when he wrote,

> ... scientific subjects are taught very largely as bodies of subject matter rather than as a method of universal attack and approach. There may be laboratories and laboratory exercises and yet this statement remains true. For they may be employed primarily in order that pupils acquire a certain body of information (Dewey 1955, p. 36).

After 1900, the evolution of the science curriculum began to respond, albeit sometimes rather slowly, to the findings of objective studies, reports of national committees, recommendations of educational philosophers, theories of learning psychologists, and recommendations of national science teachers associations and other educational organizations. Prior changes had been primarily reflections of the beliefs, biases, and pedagogical preferences of individual textbook authors.

Among the earliest calls for inclusion and emphasis of the science process skills in the high school curriculum was the November, 1913, report of a committee appointed by the Central Association of Science and Mathematics Teachers. In the report, one of five things identified that science should do for high school pupils was, "science should give pupils methods of obtaining accurate knowledge, which method should assist in solving pupils own problems (Caldwell et al. 1914, p. 157)."

One of the well-known seven cardinal principles of secondary education was "command of fundamental processes (Bureau of Education 1918, p. 11)." At the time, the fundamental processes were interpreted to be those associated with reading, wirting, arithmetical computations, and oral and written expression. Over the years this interpretation has changed rather dramatically. In 1976, a panel formed by the National Education Association (NEA) suggested adding, among others, the fundamental processes of

1. "the ability to see relationships and make correlations
2. "the skills of sorting, weighing, and then acting on data
3. "evaluating choices and making decisions wisely despite the current information and misinformation glut (Shane 1977, p. 45)"

While they were not for the most part referred to using the same terminology as today, the science process skills were considered by many to be an important element of science education during the 1930's and 1940's. Heiss et al. (1940) identified the science process skills, under the general descriptor "method of attack on problems" as one of the major goals of science teaching.

The National Society for the Study of Education (Henry 1974) reported a movement toward generalized science courses that addressed the more immediate needs of the common uses of science; also identified were a number of science process skill objectives including interpreting data, measuring, hypothesizing, and experimenting.

A Sputnik-fueled surge of interest in science education in the late 1950's and early 1960's accelerated dramatically the rate of change in the goals, instructional materials, and teaching methodology of science education. The "new" curricula that emerged viewed science primarily as a mode of inquiry. In the benchmark The Process of Education, Bruner (1960) emphasized that "mastery of the fundamental ideas of a field involves not only the grasping of general principles, but also the development of an attitude toward learning and inquiring, toward guessing and hunches, toward the possibility of solving problems on one's own (Bruner 1960, p. 20)."

In his articulation of a unitary philosophy of the curriculum for general education Philip Phenix emphasized that, "it is more important for the student to become skillful in the ways of knowing than to learn about any particular product of investigation. Knowledge of methods makes it possible for a person to continue learning and to undertake inquiries on his own (Phenix 1964, p. 11)."

The National Science Teachers Association (NSTA) has championed the science process skills as desirable learning outcomes in three major position statements. A strong case is made for science process skill development in Theory into Action...in Science Curriculum Development (National Science Teachers Association Curriculum Committee 1964), "School Science Education for the 70's" (National Science Teachers Association Committee on Curriculum Studies: (K-12 1971), and "Science-Technology-Society: Science Education for the 1980's" (National Science Teachers Association 1982).

One of 28 cardinal premises for educational change during 1976-2001, as suggested by an NEA International Panel, is "in studying possible futures, the natural and physical sciences, both in content and methodology, should serve as illustrations of truth-validating inquiry (Shane 1977, p. 67)."

The results of an opinionnaire completed by 352 people representing the leadership of the National Science Teachers Association, Council for Elementary Science International, National Science Supervisors Association, Association for Education of Teachers in Science, and National Association for Research in Science Teaching reinforce the valuing of the science process skills by the science education community. Yager (1980, p. 29) reported that "it is interesting to note that goals centering on central concepts and the processes of science are by far the most common goals listed by individuals in all five groups."

Science Process Skill Research

Unified Science

Considering the relatively small number of unified science programs compared to the more traditional approaches to high school science, the unified science education process skill research base is quite large. The reader is reminded, however, that there is a very small total high school level process skill research base.

Unified science instructional materials are organized around themes appropriate for viewing the scientific enterprise as a unified way of developing and using knowledge. One of the organizational themes that has been found to be especially useful in unified science education is the science process skills. The particular science process skills that are most valued are those that are most pervasive in the various science disciplines. Readers interested in additional information about unified science education are referred to appendix H, where the approach is discussed in detail.

At the University of Chicago Laboratory School, unified science students enrolled in a locally developed course titled Natural Science (NS) were compared to students studying Time, Space, and Matter (TSM) using the Test on Understanding Science (TOUS) and a subject matter test (SMT). Pretest/posttest results found both groups with significant gains on both tests. Further analysis demonstrated that in both years the NS students scored significantly higher than their TSM counterparts on the TOUS test. It was concluded that the NS course was very effective in teaching students about the nature of scientific theories as well as improving their skills at interpreting graphs and making inferences from data. NS was found to be weak in teaching students to answer very general questions on the methods of scientists, teaching about animal classification, teaching students to distinguish interpretations from observations, and in helping students learn to select information which would support a given theory (McCann 1968).

Cossman (1969) reports an evaluative study of a course in Science and Culture at the University of Iowa Laboratory School. The experimental group was composed of 21 students from grades 11 and 12, while the control group was created by selecting other students from within the school. One aspect of the study was testing for understanding of the scientific processes, using Subscore III of the TOUS test. Pretest/posttest application of the TOUS found gain significant at the .01 level for the experimental group, and a comparison of the experimental group to the control group found a significant difference at the .01 level favoring the experimental group.

The first year of the Portland Project course of study was evaluated in Bellevue, Washington, in a study reported by Hansler (n.d.). The study was conducted over the 1970-71 and 1971-72 school years and compared Portland Project (Integrated Science) students at Newport High School with control groups at Newport and Interlake High Schools. Posttest application of the Processes of

Science Test (POST) found no significant differences between Portland Project students and control groups during either year.

An evaluative study of the Monona Grove, Wisconsin, High School four-year unified science program included a comparison of its unified science students with 2944 Wisconsin students who had experienced traditional high school science. Comparisons of percentage deviations from the mean of the Wisconsin Inventory of Science Processes (WISP) were made in groups based upon the number of years of high school science completed. The Monona Grove students' mean was reported to have exceeded the Wisconsin comparison group mean by three percent or more for all comparisons, with the two years of high school science group showing the greatest difference (Pfeiffer 1973).

The T.H.I.S. unified science program was studied in five Illinois school districts during the 1972-73 school year, with 352 students in grades 9 through 12 involved. T.H.I.S. students at all grade and ability levels were reported to have consistently scored above the standardized mean in three of the five schools using the TOUS as a posttest (Yonke et al. 1973).

Harkness and Norton (1981) reported a study of ninth-grade students enrolled in a locally developed unified science course in Wausau, Wisconsin. The unified science students were compared to a control group randomly selected from a population of students studying Introductory Physical Science (IPS). The instrument used was a locally developed 16-item science process test. A two-way analysis of variance by treatment and sex found no significant differences.

Worthington (n.d.) reported a study conducted in New Shrewsbury, New Jersey. An experimental group of 22 9th-grade unified science students had their scores on the Interaction of Matter and Energy (I.M.E.) final examination compared to national I.M.E. results. For Part II, which consists of 35 items and is concerned with science skills, the experimental group was reported to have scored 23.7, with the national I.M.E. score being 22.8. A pretest/posttest application of the TOUS found no significant differences.

A two-year study of a tenth-grade course known as Science: A Way of Knowing was reported by Aikenhead (1980). Part of the study involved a pretest/posttest administration of the Science Process Inventory (SPI). Mean gains both years were reported to be large when compared to those found in the literature, and matched pairs t-testing showed significance at the .001 level. Among other findings reported were generally clarified ideas about observations and models and increased insights into the nature of classification schemes and the processes of scientific inquiry.

Some of the studies of the early integrated science courses are worthy of mention, not because they dealt directly with the science process skills, but because they demonstrated that integrated science courses were viable alternatives to the separate discipline-oriented courses. These findings gave interested science educators confidence and motivation, as well as the beginnings of a research base. These studies contributed to the further development of integrated/unified science courses. In addition, many of the instruments used (e.g., PSSC physics examinations, ACS chemistry tests) did have questions that required the application of some of the science process skills, such as interpreting data and inferring, in order for the student to respond successfully. Among these studies were those of Lerner (1964), Fiasca (1966), and Blessing (1970). In general, they found students in integrated courses to perform as well as or superior to the students in separate courses on the various subject matter tests that were used, although the findings favoring the integrated groups were often not statistically significant. Johnson (1968) conducted a similar comparison of students in an integrated chemistry-physics course to those in separate courses, but also included the TOUS test. All groups were reported to have made significant gains on TOUS, but no significant differences were reported between groups.

Summary

In general, unified science students have been found to perform well on science process skill assessments. In most comparative studies cited, the unified science groups had mean scores or mean gain scores reported that exceeded those of the control groups. In no cases were the unified science students reported to be significantly lower than the control group. In pretest/posttest measurements for unified science groups, increases or significant increases were reported in all but one case. However, a note of caution is justified, since only two of the studies indicated an effort to experimentally or mathematically control for potentially important covariates (e.g., academic ability, pretest score, sex).

Biology

High school biology, especially the Biological Sciences Curriculum Study (BSCS) courses, appears to have more science process skill studies reported in the literature than any other type of science typically implemented at the high school level.

Doran and Sellers (1978) investigated the relationship between students' metnal ability, gender, and biology achievement on science process achievement in experimenting, predicting, and concluding. Mental ability was reported to correlate (0.78) positively with process achievement, but biology achievement and mental ability combined only accounted for nine percent of the variance on process skill achievement for 320 tenth-grade biology students. Males were also reported to have been found to achieve higher than females on science processes.

Castelli (1970) studied the effects of BSCS Single Topic Inquiry Films on the process skill development of students in BSCS Blue Version Biology. Process skill knowledge was measured with the Processes of Science Test (POST). The BSCS control group gained 6.27 points on the POST, while the experimental BSCS class gained

7.13. While the author reports no significant difference between the two groups, no comment was made regarding the significanct of either group's mean gain during the course of the study.

A study of the effect of BSCS "Invitations to Enquiry" on the knowledge of the processes of science of ninth grade BSCS biology students was reported by Starr (1970). The POST was used to assess level of science process skill knowledge. No significant differences were reported between the experimental and BSCS control groups, using IQ and the pretest as covariates. No comment was made by the investigator regarding the significance of the gain by each group, but reported gains were 1.378 and 1.105.

Grgurich (1970) conducted an investigation of three ability-grouped biology classes using BSCS Blue, BSCS Yellow, and a locally developed general survey course. Pretest/posttest mean gains and sex relationships were studied for three objectives, one of which dealt with increased understanding of and ability to use the processes of science. The POST and Watson-Glaser Critical Thinking Appraisal were used for measurement of change in the process objective. The high ability BSCS Blue group and low ability survey course group showed no significant difference when compared to comparable ability grouped non-science control groups. The middle ability BSCS Yellow group demonstrated a significant advantage over the non-science control on the POST, but there was no significant difference found on the Watson-Glaser Critical Thinking Appraisal.

Significant pretest/posttest POST gains at the .01 level were reported for the high and medium level BSCS groups and the high and middle ability non-science control groups. The low ability biology and non-science control groups showed no significant gains. In only one comparison were sex-related differences found to be significant. In the high ability non-science control group females were significantly favored on four of seven processes.

Montgomery (1969) used the POST to assess the process skill learning outcomes and retention of 288 ninth- and tenth-grade biology students. No significant ($p < .05$) differences were found on the POST between BSCS and traditional students, ninth- and tenth-grade students, or male and female students. No significant difference was reported between the pretest/posttest scores of BSCS students. The only significant ($p < .05$) difference on retention favored BSCS students over traditional students. The retention period investigated was the summer vacation period.

Gennaro (1964) used the BSCS Impact Test as a posttest with 49 BSCS biology students. No significant ($p < .05$) differences were reported between BSCS Yellow and BSCS Lab Block with BSCS Yellow reading student scores, male and female scores, or interactions.

Lance (1964) used Noll's What Do You Think? Test to investigate scientific attitudes in terms of habits of thinking, including observation, with 260 ninth- and tenth-grade biology students in 4 high schools. Using ANCOVA with pretest, IQ, academic average, and chronological age as covariates, no significant differences in test score gains was found between BSCS Green and traditional students. No pretest/posttest significant differences were reported for sex, school, grade level, IQ, academic average, or age. Pretest/posttest gains were reported to have been significant at $p < .01$.

Cheong (1971) developed a Test of Inquiry Processes (TIP) to use in a study of 124 biology students distributed through 13 different classes in 3 high schools. Interpreting data was one of three process skills studied. A positive correlation of 0.65 (significant at $p < .01$) was reported between TIP scores and The Cooperative School and College Ability Test (SCAT) scores of students.

Lazarowitz (1981) used a specially developed 13 question Biological Classification Ability Instrument (BCAI) to investigate classification skills of ninth-grade biology students. Findings reported included a positive correlation of about 0.70 between general intelligence and classification ability and boys significantly ($p < .05$) favored for classification ability.

Marek (1981) reported a correlation of 0.30 between cognitive development and inquiry skill achievement for 92 ninth- and tenth-grade biology students.

Story (1974) studied the effect of the BSCS Inquiry Slides on the process skill knowledge of tenth-grade biology students. After ten weeks of treatment, the only significant ($p < .05$) difference reported was when BSCS students were compared to non-BSCS students.

The author concluded that the BSCS program was apparently a greater contributing factor than the BSCS Inquiry slides in developing the process skills.

Smythe (1972) reported that his findings from a study involving 286 tenth-grade biology students, using the POST for gathering data, suggested that the teaching methods of classroom teachers appeared to be more important in determining outcomes in BSCS biology than imposed time blocks or course content.

In a meta-analysis of 59 studies, El-Nemr (1979) reported that students taught biology by the inquiry mode of instruction improved their science process skills more than students taught biology by the traditional approach; the development of process skills was reported to be the most affected outcome variable of teaching biology as inquiry.

Cobern (1979) reported that science concept and process knowledge of biology students loaded on separate factors. This provided some evidence of structure within each category.

Summary

The biology studies generally report gains in measures of student science process skill knowledge, but the gains were not always statistically significant. In three cases, no comment was made regarding the statistical significance of pretest/posttest differences.

Several studies (Castelli 1970; Starr 1970; Gennaro 1964; Story 1974) investigated the impact of special teaching strategies and materials on the development of the science process skills with biology students. No significant ($p < .05$) differences were reported due to the experimental treatment.

Four studies reported positive correlations between measures of science process skill knowledge and other variables; Doran and Sellers (1978), Cheong (1971), and Lazarowitz (1981) reported correlations of 0.78, 0.65, and 0.70, respectively, with mental ability. Marek (1981) reported a correlation of 0.30 between level of cognitive development and inquiry skill achievement,

Six studies (Doran and Sellers 1978; Grgurich 1970; Montgomery 1969; Gennaro 1964; Lance 1964; Lazarowitz 1981) reported findings relative to the sex variable and science process skill achievement. No significant ($p < .05$) differences were reported in three studies, males were favored in one and significantly ($p < .05$) higher in another, and females significantly favored in one. However, the females who were favored were in a non-science control group.

Two studies (Montgomery 1969 and Lance 1964) reported no significant ($p < .05$) difference between the science process skill achievement of ninth- and tenth-grade students.

A variety of other variables were studied in relation to the science process skills in single studies only. One study (Cobern 1979) examined student knowledge of concepts and processes and reported loading on different factors, which suggested some structure within each category.

The only retention study (Montgomery 1969) spanned only the summer vacation period and found BSCS students significantly ($p < .05$) favored over traditional students.

Physical Science

Fritz and Szabo (1974) studied 167 eighth-grade students in a comparison of the Intermediate Science Curriculum Study (ISCS), Level II, and Introductory Physical Science (IPS). The POST was used as the criterion measure. An analysis of covariance controlling for several forms of ability, including math and science, found no significant differences between the groups.

Butzow and Sewell (1971) used pretest/posttest measurements with the TOSP with 92 eighth-grade IPS students to assess changes in process skill knowledge. As a result of studying the first five chapters of IPS, significant gains were found by various ability level groups in ability to observe, compare, classify, quantify, measure, experiment, and infer. No significant differences were found in ability to predict.

It appeared that there was a relationship between intelligence and process skills such that more intelligent groups of students were further down a continuum of difficulty at the onset of instruction. It was found that lower ability level students showed no significant gains on the test as a whole or on any of the processes.

Abegg and Skvarcius (1977) studied eight process skills with physical science students in grades eight through ten; among these skills were interpreting data, inferring from observations, and using models. Findings showed IPS students to have made significantly greater gains ($p < .05$) on five of the eight skills than did students in other physical science or life science classes.

Batten (1976) reported that ninth-grade earth science students who had experienced IPS instruction in the eighth grade had higher process skill ability than students who had experienced ISCS and physical science other than IPS.

Coulter et al. (1981) examined student formal operational ability and the teaching of science processes with 61 ninth- and tenth-grade IPS students in a suburban high school. The findings indicated that formal operational students did significantly ($p < .05$) better than non-formal operational students on "experimental" process skill items.

Summary

Even though the number of studies is rather small, physical science, and especially IPS, generally appears to be effective in developing the science process skills of most students in grades eight through ten. There is some doubt about the effectiveness of IPS in increasing the science process skill knowledge of higher ability students.

Butzow and Sewell (1971) reported an apparent relationship between student intelligence and process skill knowledge. Batten (1976) reported that IPS instructed students significantly outperformed other students on science process skill ability during the year following the IPS experiences.

Coulter (1981) reported findings indicating a significant science process skill advantage for students with formal operational ability.

Earth Science

Erickson (1971) reported ninth-grade students using the Earth Science Curriculum Project (ESCP) materials to have had a five percent greater adjusted pretest/posttest mean increase on the TOUS than a control group using a textbook/lecture-demonstration method. The 834 ninth-grade students were in 11 junior high schools.

Batten (1976), when studying 40 sections of ninth-grade students in some Virginia schools, found that students' SCAT quantitative scores were significant ($p < .05$) predictors for the use of science processes as measured by the TOSP. Eighth-grade science was also found to be a significant ($p < .05$) predictor, along with the teachers' age, sex, mathematics hours, teaching endorsements, years of NSF institutes, and number of Mathematics and Science Center workshops completed. Younger, female teachers and those endorsed in earth science were favored.

DeVito (1966) conducted a study of scientific model building in an earth science context with 1000 eighth-grade general science students. Three model building units were prepared for the study, as was a Test of Understanding of the Elements of Model Building. Significant ($p < .01$) pretest/posttest gains were made by all composite groups, with only one accelerated track subgroup not making significant gains. DeVito also reported that the order in which the three units were experienced produced no significant differences.

Chemistry and Physics

Chemistry

Seymour and Sutman (1973) report that eleventh grade chemistry classes in two high schools taught following a Chemistry Course Guide for Philadelphia Comprehensive High Schools did not develop knowledge of the processes of science. The study was conducted during the 1969-70 school year and used the Wisconsin Inventory of Science Processes to assess process skill knowledge.

Abegg (1969) pretested and posttested 1009 high school chemistry students in Kansas and Nebraska with the TOUS. Significant gains were reported for all groups; in addition, it was reported that the gains were significantly related to class and teacher differences and not to the materials used in the different groups. The most dominant factor appeared to be the teacher, while no significant positive correlations were found between TOUS scores and science background, general intelligence, or achievement in chemistry.

Physics

Petit (1969) studied 368 physics students in Michigan. PSSC and other physics courses were reported to have produced similar student knowledge of the processes of science as measured by the Science Process Inventory.

Crumb (1965) used the TOUS to assess the understanding of science developed by 1275 physics students in four states. Both PSSC and traditional students had significant ($p < .001$) gains during both semesters.

Chemistry and physics

In a study of 464 male high school seniors designed to evalute differences in cognitive processes related to science, Nardine (1969) reports that college-bound students who had completed both physics and chemistry scored significantly higher on the POST than college-bound students who had completed neither physics or chemistry. College-bound seniors who had not studied either chemistry or physics scored significantly higher than their non-college bound counterparts. In addition, those college-bound subjects who had completed both physics and chemistry were found to have no process deficiences, with deficiences interpreted as having more incorrect than correct responses to a set of questions keyed to a process. All other groups were found deficient in at least six of the eight process areas.

Other Science Process Skill Research

Pettus and Haley (1980) conducted a study to determine if there were relationships among the science process skill levels of high school students and their classification according to sex, age, grade level, number of completed science courses, and interest in science careers. The subjects were 505 Youth Conservation Corps participants in Virginia in 1977. The Test of Science Processes (TOSP) was used to measure process skill level. Among the findings were the following:

1. Mean scores increased with grade level
2. Mean scores for girls were higher than for boys
3. Mean scores for students with high levels of science career interest were higher than those for non-interested students
4. Mean scores increased with age and the number of science courses taken, but not for all skill subscores

Stepwise multiple regression analysis indicated that 24 percent of the total variance was accounted for, with the number of science courses taken accounting for 14.75 percent. The number of science courses taken was the most important predictor for observing, comparing, quantifying, and predicting. Age was the most important predictor for classifying and measuring. Grade level was the greatest contributor to accounting for the variance on experimenting and inferring.

The authors concluded that while the number of science courses completed showed the strongest relationship to overall science process skill performance level, the relationship was not considered to be very strong, and that grade level and age ranges of their subjects showed little relationship to overall science process skill levels.

Dochterman (1970) when summarizing the results of the 1969 National Assessment of Educational Progess (NAEP) national science results has pointed out that there is an observed expansion of knowledge and growth in skills as age increases from 9-17. However, only the 17 year olds of the ages tested would typically be found in high school.

In another NAEP report, the Education Commission of the States (1975) indicated that in the area of scientific principles and procedures the percentage of students able to perform activities was directly related to their age. The activities included using apparatus to conduct testing procedures and simple experiments, the application of knowledge to the observations of materials in order to create generalizations, and the demonstration of principles by the use of models.

Welch and Pella (1968) administered the Science Process Inventory (SPI) to 839 students in grades 10-12. No significant differences were found between the scores of students in different grade levels.

Hinerman (1971) reported significant positive correlations between WISP scores and semesters of high school mathematics and science completed. These two variables accounted for 21.8 percent of the variance of WISP scores.

Daume (1981) compared science process skill achievement as measured by the Comprehensive Test of Basic Skills: Science to reading achievement, mathematics achievement, attitudes toward science, and sex for ninth-grade students in two junior high schools. When the variables listed earlier were held constant, no significant ($p < .05$) difference was found between ISCS and traditional students. No sex difference was found with ISCS students when reading and mathematics achievement were controlled, while in the traditional program, males scored higher than females.

Padilla et al. (1981) examined integrated process skill and formal thinking abilities of 80 secondary students to determine the relationship, if any, between the two. The Test of the Integrated Process Skills (TIPS) and Test of Logical Thinking (TOLT) were used. Process skill subtest correlations to total TOLT were high and ranged from 0.61 to 0.99; the total TIPS correlation to total TOLT was 0.73 ($p < .001$).

Boulanger (1981) reported correlation coefficient means of 0.49 for general ability and 0.42 for prior achievement for process learning in a meta-analysis of 20 studies.

Effect Size

Overall effect sizes reported for high school student outcomes in the science process skills are very limited. Sweitzer (1982) reports a mean effect size of .436 for 19 effect sizes related to student outcomes, 9 of which measured the knowledge of science process skills. However, most of these were from pre-high school studies. El-Nemr (1979) studied 250 effect sizes from 59 experimental studies in which the traditional teaching of biology and biology taught as a process of inquiry were compared. The mean effect size for 30 effects concerned with the science process skills was .50, and the mean for high school level studies (19 effect sizes) was 0.436. Glass et al. (1980, p. 127) comment that an effect size of .40 is "a fairly large effect."

In reporting the findings of a meta-analysis project, Kahl et al. (1982) indicated that the average sex-related differences effect size for the science process skill outcomes at the high school level was 0.07. The effect size was calculated from three studies and favored males.

Boulanger (1981) reported a mean annual effect size increment of 0.43 for science process learning; however, this value is based upon only two studies in grades 9 through 12.

Summary

The most consistent finding reported is a strong relationship between intelligence and/or academic ability-achievement and the level of science process skill knowledge. This relationship appears sometimes to limit the observed process skill growth of high ability students, especially in the physical sciences. Several studies reported significant positive correlations between level of cognitive development and science process skill knowledge. These correlations were typically smaller than those for the intelligence-achievement variables.

Sex differences in process skill studies appear to be rather small, and the findings are somewhat contradictory. The individual studies cited found no significant difference in one-half the cases. Males were favored in three comparisons, and females in two. However, one of the female advantages was reported in a non-science control group. The meta-analysis study of three studies involving the science process skills found a small difference favoring males.

Age emerged in several studies as an important variable in accounting for variance in science process skill measures. Age, however, appears to be more important over a large time span (e.g., the years of formal schooling) than during the high school years. One high school study did find process skill knowledge increasing with age and a close relationship between age and ability to classify and measure.

Grade level was addressed in four studies. One high school level study reported science process skill knowledge to increase with grade level, and there appeared to be a close relationship between ability to experiment and infer and grade level. The three other studies found no significant differences between grade levels.

The number of science courses completed does appear to have a relationship to process skill knowledge. In general, the greater the number of science courses completed, the higher the level of science process skill knowledge. In one study, the number of science courses completed was found to be the strongest predictor of science process skill knowledge. Students with high levels of science career interest, and therefore probably completing more science courses, were also found to have high levels of science process skill knowledge.

Little can be generalized about the effect of different types of science classes on the development of the science process skills. Physical science courses appear to foster substantial process skill development, especially among lower ability students. Unified science studies indicate that unified science courses consistently produce increased process skill knowledge and have favorable results in comparative studies. Biology classes show great variation, in some instances appearing to promote rather large gains in science process skill knowledge and in other cases demonstrating either low gains or gains no different from non-science control groups. Meta-analysis results suggest that development of process skills may be the most affected outcome variable of teaching biology as inquiry. There is also evidence in all types of science suggesting that the teacher (e.g., training, methodology, emphasis) may be a more important variable than type of science in impacting science process skill outcomes.

Effect sizes for science process skill outcomes appear to be reasonably large, with means in the vicinity of 0.40 to 0.50.

The ability to generalize from the reported results of science process skill research is confounded in some cases by the lack of critical information, and in others by the investigator's choice not to control for potentially important variables (e.g., academic ability) or apply tests of significance when assessing differences. Critical information often not reported includes instructional emphasis on the science process skills (e.g., percentage of instructional time devoted to the process skills) and comments relative to the instructional strategies used. The latter may be especially critical, since a meta-analysis by Bredderman (1982) of 57 elementary-level studies found an average improvement of 20 percentile units on science process tests for students in activity-based programs over those in other programs.

Research Related To Achievement in Science

Due to the substantial volume of studies in this area, heavy reliance was placed on meta-analysis studies and research reviews.

Wallberg (1980) reported that student learning in science depends upon five variables; these five variables are student ability, student motivation, student age or developmental level, instructional quality and quantity, and social-psychological simulation of the home, peer, and classroom environments.

Wallberg et al. (1980) reported an overall ability-cognitive outcome correlation of 0.48 from 34 studies over a 16-year period; ability was found to account for an average of 23 percent of the variance in science learning. Measurements of student ability were found to be better predictors of cognitive achievement than developmental measures (grand mean correlation 0.40), whose correlation peaked in grade nine. Student motivation was found to have a mean correlation of 0.37 from five studies. Age within a grade was a weakly correlating variable, with a mean of -0.01 from three studies. Age was found to be a positive predictor only across grade levels. Quality of instruction correlated in the vicinity of 0.25 to 0.30 for 51 studies, while quantity of instruction, from 3 studies, correlated with a mean of 0.19. Home and peer environment from 18 studies correlated at 0.24 and 0.25, respectively, while classroom environment from 12 studies had a mean correlation of 0.19.

The results of a meta-analysis project including 169 studies reported by Kahl et al. (1982) are in general agreement with the findings reported by Wallberg et al. The mean correlation for cognitive outcomes were reported as 0.45 for mathematics ability/performance, 0.43 for reading ability, 0.44 for verbal/language ability, 0.45 for spatial ability, 0.46 for IQ, 0.50 for cognitive level of development, 0.34 for attitude/motivation, 0.28 for socioeconomic status, 0.52 for internality, and 0.48 for study skills.

Kyle et al. (1982) conducted a meta-analysis of 105 experimental studies that examined the effects of the new science curricula on student performance. The results reported indicate that across all new curricula, students have performed better than students in traditional courses on measures of general achievement, analytic skills, process skills, and related skills (e.g., reading, communication), as well as having developed more positive attitudes towards science. The average student in a new curriculum was reported to exceed the performance of 63 percent of the students in a traditional curriculum.

Effect Size

Wallberg et al. (1980) report an annual cognitive outcome effect size mean increment of 0.28 over grades 4 through 10, with the increments relatively constant. A number of instruction-related mean effect sizes were also reported for cognitive outcomes. Among these were mean effect sizes of 1.03 for preinstructional strategies (e.g., behavioral objectives, advance organizers), -0.22 for teaching strategy (deductive favored), 0.89 for training in scientific thinking, and 0.74 for more highly structured learning. The overall quality of instruction mean effect size was 0.55. The overall weighted mean of the curriculum effect sizes is 0.308, and favorable to the innovative curricula.

Kahl et al. (1982) reported average sex-related differences effect sizes in secondary cognitive science outcomes for general science (0.29), biology (0.02), earth science (0.07), and physical science (0.33). All of the differences favored males.

Summary

The agreement is generally good between the various studies relative to which variables are important in accounting for cognitive learning and the relative impact of each of these variables. The most noticeable difference was in the mean correlation of cognitive level of development, which was 25 percent higher in the most recent study. The variables of most interest, in decreasing order of importance, are ability/achievement, developmental level, motivation, socio-economic factors, quality and quantity of instruction, and age. Student study skills may also be an important variable to consider.

The findings from the process skill research are consistent with those for cognitive outcomes in general. The most important difference appears to be in effect sizes, where process skill values are often considerably larger than those reported for cognitive outcomes in general.

Reading and Testing

As reading is an important consideration in the learning of science, it is an important factor to consider when measuring a variable by the use of a paper-and-pencil instrument. It has been noted (Mallison 1972, p. 135) that students at the junior and senior high school levels had greater difficulty in comprehending the nontechnical words in their science books and materials than they had in comprehending the technical terms. Therefore, the nontechnical choice of words used in a written test may be as important as the vocabulary load of the technical terms.

Reading formulae are useful, but they present two potentially important problems. First, the average reading level of a test may be suitable but certain questions or groups of questions may be exceptionally difficult for all or part of the subjects. This is an especially important consideration if groups of questions are used to generate subscores. In addition, there are a number of factors (e.g., interest generated, use of illustrations) not taken into account by the various formulae. In an effort to address this concern during the development of the Science Process Competency Test (SPCT), the investigator used student feedback during and after the piloting of the instrument in conjunction with the Lorge formula.

The organizational structure of the test, both within and between items, is an important potential variable, as is the use of typographical aids, such as underlining. Aldridge and Anderson (1960) concluded that students' capacity to know the meaning and to identify the form of words enabled them to score somewhat higher on science tests.

Another important consideration in measuring a cognitive skill is the relationship of forced choice paper-and-pencil items, open ended paper-and-pencil items, and non paper-and-pencil performance measures. Okey et al. (1981) correlated responses of the forced choice and open ended paper-and-pencil measures of some science process skills and found the average correlation to be about 0.80. The subjects were ninth-grade science students, and the process skills involved were the integrated process skills identified by the AAAS. No study was identified in the area of high school level science process skill measures that correlated paper-and-pencil measures to non paper-and-pencil performance measures.

This Study and the Literature

This study will contribute in several ways to the evolution and substance of the high school level science process skill research base. The regression analyses provide further knowledge regarding the variables important in accounting for variance in the measurement of science process skill knowledge. An area where the findings are basically inconsistent with those reported in the literature is the importance of grade level in science process skill development. The study provides additional insight into the importance of type of science, including teacher emphasis, and makes an apparently unique contribution of science process skill retention through the high school years.

The inclusion of effect sizes will make the results readily amenable to comparison with the results of the increasing number of meta-analysis studies. In addition, the SPCT developed for the study provides another instrument use/development option for the science education community. Hopefully, the design of the study itself may provide a useful model for others wishing to engage in applied research of the science process skill knowledge/development of junior high school and high school age students.

CHAPTER III

THE STUDY--DESIGN AND METHOD

This chapter presents the requisite information regarding the following:

1. Population investigated
2. Two samples from which data were gathered
3. Science courses and science teachers with which the samples interacted
4. Instrumentation
5. Data collection procedures
6. Statistical analyses procedures

Population

The population investigated consisted of all students in grades 9 through 12 enrolled during the 1981-82 school year in the three comprehensive high schools of Oregon's North Clackamas School District. Table 2 provides student enrollment information for these high schools as of 30 September 1981.

TABLE 2

STUDENT ENROLLMENT IN THE THREE HIGH SCHOOLS OF
THE NORTH CLACKAMAS SCHOOL DISTRICT

School	Grade 9	Grade 10	Grade 11	Grade 12	Total
Clackamas	298	294	321	322	1235
Milwaukie	315	326	301	271	1213
Rex Putnam	355	339	300	335	1329
Total	968	959	922	928	3777

SOURCE: Interview with Dan Browne, North Clackamas School District Planning & Evaluation, Milwaukie, Oregon, 26 February 1982.

The North Clackamas School District is located in a suburban/rural setting to the immediate south of Portland, Oregon. Detailed information regarding the history of the school district, its setting, educational facilities, and student population can be found in appendix A.

Samples

Sample One

Sample One data were used for testing hypotheses one through four, plus hypothesis nine. With some exclusions discussed in the following paragraphs, Sample One consisted of students enrolled in the first available nonprerequisite science courses that would fulfill their high school graduation requirement.

The state and school district graduation requirement in the area of science is completion of one year of laboratory science during grades 9 through 12 (Oregon Department of Education 1980). If the mandatory year of high school laboratory science has not already been completed, it is required during grade ten at Clackamas and Rex Putnam High Schools. Laboratory science is required during grade nine at Milwaukie High School. Table 3 provides complete enrollment information for these first-level laboratory science courses.

TABLE 3

TOTAL ENROLLMENT IN FIRST-LEVEL SCIENCE IN THE THREE SAMPLE HIGH SCHOOLS

Type of Science	Grade 9			Grade 10			Grade 11			Grade 12			Total
	C	M	P	C	M	P	C	M	P	C	M	P	
Biology	0	166	0	195	39	0	19	13	0	6	8	0	446
Earth & Space	0	99	0	0	13	0	0	2	0	0	4	0	118
Physical	75	0	0	50	0	0	10	0	0	4	0	0	139
Unified	0	29	72	0	9	259	0	12	26	0	0	11	418
Total	75	294	72	245	61	259	29	27	26	10	12	11	1121

NOTE: Columns headed "C," "M," and "P" designate students enrolled at Clackamas, Milwaukie, and Rex Putnam High Schools, respectively.

Delineation of Sample One

Each of the high schools has provisions for students identified as having special learning difficulties (e.g., low reading ability) to be placed in alternative programs for purposes of fulfilling their high school science requirement. These special classes are known as Options Biology at Clackamas High School, Science at Milwaukie High School, and Science Concepts at Rex Putnam High School. These programs and the students enrolled in them have been excluded from Sample One and table 3.

To further delineate Sample One, it was decided to exclude non-English speaking students, students in grades 11 and 12, and students who already attempted or completed one or more semesters of high school science. Some multiple Science Process Competency Test (SPCT) scores for students resulted from simultaneous enrollment in more than one first-level science course. Only the score from the first administration of the SPCT was retained in the data pool.

Non-English speaking students were excluded from the sample due to the probable inability of being able to effectively measure their competency performance level with an English language instrument. The four students who qualified for this exclusion were identified on the basis of their treatment as "English as a Second Language" (ESL) students in their respective high schools.

Students in grades 11 and 12 who were enrolled in first-level required science courses were excluded because they did not represent the grade level norm for this level of instruction. These

116 students constituted only ten percent of the total enrollment and were generally enrolled at a later grade level due to some unusual circumstance, such as failure in a prior effort to fulfill their science requirement, erratic school enrollment pattern, or having transferred from a school district or state with a different science requirement. The information available on these students indicated that at least 47 percent of them had experienced prior high school science instruction and would be subject to exclusion under that criterion as well.

All students who had attempted or successfully completed prior high school science courses were excluded because their competency performance level may have been influenced by the prior high school science instruction. A total of 152 students were identified in this category.

Students enrolled simultaneously in two or more first-level science courses were administered the pretest in each class. Since taking the test more than once is a unique characteristic and the completion of the test the first time may influence the score the second time, only the score from the first pretest completed was used in data analysis. However, only one student was found to be in this situation.

After the exclusions just discussed had been made, the Milwaukie High School tenth-grade Earth and Space Science group had been reduced to two students and the same school's tenth-grade Integrated (Unified) Science group to three students. Due to the small size of each of these groups, they were both excluded from Sample One.

Final composition of Sample One

Table 4 summarizes the students retained in Sample One for purposes of data analysis and hypotheses testing.

TABLE 4

SAMPLE ONE ENROLLMENT BY GRADE LEVEL
AND TYPE OF SCIENCE

Type of Science	Grade 9			Grade 10			Total
	C	M	P	C	M	P	
Biology	0	160	0	148	14	0	322
Earth & Space	0	91	0	0	0	0	91
Physical	73	0	0	44	0	0	117
Unified	0	27	70	0	0	218	315
Total	73	278	70	192	14	218	845

NOTE: Columns headed "C," "M," and "P" designate students enrolled at Clackamas, Milwaukie, and Rex Putnam High Schools, respectively.

Sample Two

Sample Two data were used for testing hypotheses one through three and five through eight. The sample consisted of 210 randomly selected students not enrolled in their first year of high school science. The students were selected from all grade levels following the one in which science was required in each high school. Milwaukie had students selected from grades 10 through 12, while Clackamas and Rex Putnam had students chosen from grades 11 and 12. In each school, 30 students were included from each participating grade level. In addition to being randomly selected, students had to have completed their required year of science in the North Clackamas School District and have either CAT scores available or the results of some other standardized test (e.g., Comprehensive Test of Basic Skills, SRA Achievement Series, Stanford Achievement Test, Iowa Test of Basic Skills) that were reported in percentile levels.

Sample Two selection procedure

The students from each grade level in each school were selected by the use of a 5000 random digit table contained in Appendix A of Statistical Methods in Education and Psychology (Glass and Stanley 1970). The numerical student identification corresponded to the location of each student on an alphabetized list of the students in their grade level within each high school. If a selected student did not fulfill the selection criteria, a replacement student was selected using the same process and table.

In order to assure a useable sample of 30 SPCT scores, the actual number of students selected for testing at each grade level in each school was 50. The specific number of additional students selected was based upon the recommendations of the high school attendance personnel and student absenteeism data. When more than 30 scores were actually obtained, those retained for analysis were the first 30 in order of original selection.

First-Level Science Courses

The North Clackamas School District's framework for high school science is its single science program goal, eight corresponding minimum graduation competencies, and the requirement that all students complete one year of laboratory science. The science program goal is "the student will utilize scientific processes (North Clackamas School District No. 12 1975, p. 10)." The minimum graduation competencies are discussed in detail later in this chapter and are also found in Appendix A.

The three high schools differ in their approach to the required year of laboratory science. At Clackamas High School, those ninth-grade students permitted to enroll in science are integrated into Physical Science classes. Tenth-grade students at Clackamas may choose between Biology and Physical Science. At Milwaukie High School, the ninth-grade students may choose from Biology, Earth and Space Science, and Integrated Science. At Rex Putnam High School, all students are required to complete Science (Unified Science);

those ninth-grade students permitted to enroll in science are integrated into Science classes.

Science course credit in all high schools is granted and recorded on a semester basis. Numerical designations following descriptive course titles (e.g., Biology 1-2) indicate the semesters available and are sequential.

Planned Course Statements

The State of Oregon requires that a Planned Course Statement (PCS) be prepared for each course offered in grades 9 through 12. The PCS, as a minimum, must contain the course title, a course overview, the course goals, and where appropriate, indicators of competence assigned to the course for verification (Oregon Department of Education 1980). Copies of the PCS's for each of the first-level science courses, except Milwaukie High School's Integrated Science 1-2, are found in appendix B. The Milwaukie High School Integrated Science 1-2 course uses the same basal materials as Rex Putnam High School's Science 1-2, and the Milwaukie instructor had indicated that the only basic difference between the two courses was a slightly greater emphasis on the physical science topics at Milwaukie. Therefore, the Rex Putnam Science 1-2 PCS's provide a useful overview of the Milwaukie Integrated Science 1-2 course.

Summary of First-Level Science

Four types of science and six different science courses are used at the required science level in the three high schools. An overview of basic information regarding these courses is found in table 5. For further information, the reader is directed to descriptive material about the approach to required science in each high school which is found in appendix A, and the PCS's, which are located in appendix B.

TABLE 5

OVERVIEW OF FIRST-LEVEL HIGH SCHOOL SCIENCE COURSES IN THE NORTH CLACKAMAS SCHOOL DISTRICT

Course Title	School	Basal Textbook	No. of Sections		Number of Teachers	Ave. Class Size
			1st Sem.	2nd Sem.		
Biology 1-2	Clackamas	Biology: Living Systems Charles E. Merrill,1976	10	10	2	22.0
Biology 1-2	Milwaukie	Modern Biology Holt, Rinehart, and Winston, 1977	9	9	2	25.1
Earth and Space Science 1-2	Milwaukie	Investigating the Earth Houghtin-Mifflin, 1978	5	5	1	23.6
Integrated Science 1-2	Milwaukie	Materials developed at Rex Putnam High School	2	2	1	25.0
Physical Science 1-2	Clackamas	Introductory Physical Science Prentice Hall, 1977	6	6	2	23.2
Science 1-2	Rex Putnam	Locally developed materials, 1976-1979	19	18	4	19.4

First-Level Science Teachers

This study was designed to assess certain aspects of the development of science process skill competencies in students under the usual and existing conditions within the high schools of the North Clackamas School District. Therefore, the investigator had no input into or control over such within school variables as staff assignments, student assignments, class loads, and class schedules.

In order to gather specific information relative to the instructional staff of the first-level courses, a short Teacher Questionnaire was submitted to the teachers during early April 1982. A copy of this questionnaire is found in appendix C. Tables 6 through 8 provide a summary of the information extracted from the questionnaires.

TABLE 6

SELECTED CHARACTERISTICS OF FIRST-LEVEL SCIENCE INSTRUCTORS AT CLACKAMAS HIGH SCHOOL

Teacher No.	Sex	Course Taught	No. of Sec.	Years Exp. in Subject		Total Years H.S. Teach. Exp.	No. of Sci. Preps.	Highest Degree Earned
				Clackamas	Elsewhere			
1	F	Biology 1-2	5	4.0	7.0	12	1	M.Ed. (1975)
2	M	Physical Sci. 1-2	5	16.0	0.0	24	1	M.Ed. (1961)
3	M	Physical Sci. 1-2	1	2.0	0.0	24	2	M.A. (1971)
4	M	Biology 1-2	5	9.5	0.5	10	1	M.S.T. (1975)

TABLE 7

SELECTED CHARACTERISTICS OF FIRST-LEVEL SCIENCE INSTRUCTORS AT MILWAUKIE HIGH SCHOOL

Teacher No.	Sex	Course Taught	No. of Sec.	Years Exp. in Subject		Total Years H.S. Teach. Exp.	No. of Sci. Preps.	Highest Degree Earned
				Milwaukie	Elsewhere			
1	F	Biology 1-2	4	7	0	7	2	M.A.T. (1976)
2	F	Integrated Science 1-2	2	0	0	0	1	B.S. (1980)
3	M	Earth & Space Science 1-2	5	10	5	15	1	M.S. (1971)
4	F	Biology 1-2	5	20	5	25	1	M.S. (1965)

TABLE 8

SELECTED CHARACTERISTICS OF FIRST-LEVEL SCIENCE INSTRUCTORS AT REX PUTNAM HIGH SCHOOL

Teacher No.	Sex	Course Taught	No. of Sec.		Years Exp. in Subject		Total Years H.S. Teach. Exp.	No. of Sci. Preps.	Highest Degree Earned
			Sem. 1	Sem. 2	Putnam	Elsewhere			
1	M	Science 1-2	5	5	13	0	16	1	M.S.T. (1965)
2	M	Science 1-2	4	4	10	0	20	3	M.S.T. (1972)
3	M	Science 1-2	5	4	3	0	3	1	M.S.T. (1971)
4	M	Science 1-2	5	5	0	0	0	2	B.S. (1975)

NOTE: The "Years Exp. in Subject" columns include teaching experience with the Portland Project Integrated Science Sequence, which preceded the locally developed Science 1-2 course at Rex Putnam High School.

Elective Science Courses

Each of the high schools provides a comprehensive collection of elective science courses. The first-level courses have already been described. However, at Clackamas and Milwaukie High Schools, where more than one course is available for fulfilling the science graduation requirement, it is possible for some students in Biology, Physical Science, Earth and Space Science, and Integrated Science to be completing their required science while others in the same class are completing the same course as an elective. In both of these high schools, Advanced Biology, Chemistry, and Physics are also available as full-year elective science courses. Clackamas High School also provides the opportunity for individual students to study elective science through a Reading and Conference arrangement. Milwaukie High School has a Science Seminar course available to those students who have completed their required science and Chemistry.

Rex Putnam High School requires students to successfully complete Science 1-2 prior to enrolling in any other science course, with the exception of Natural Science. Natural Science is a project-oriented course available to students at any grade level without prerequisite. Other elective science courses are Biology 1-2, and Science 3-4-5-6-7-8-10. Science 3, 5, and 7 courses have a physics orientation, while Science 4, 6, 8, and 10 have a chemistry orientation. Table 9 summarizes the available elective science courses in the three high schools.

TABLE 9

ELECTIVE SCIENCE COURSES IN THE THREE HIGH SCHOOLS OF THE NORTH CLACKAMAS SCHOOL DISTRICT

School	Advanced Biology 1-2	Biology 1-2	Chemistry 1-2	Earth & Space Sci. 1-2	Integrated Sci. 1-2	Natural Science	Physical Science 1-2	Physics 1-2	Reading & Conference	Science 3, 5, & 7 (Physics)	Science 4, 6, 8, & 10 (Chemistry)	Science Seminar
Clackamas	X	X	X				X	X	X			
Milwaukie	X	X	X	X	X			X				X
Rex Putnam		X				X			X	X	X	

Instrumentation

An investigator-developed Science Process Competency Test (SPCT) and the California Achievement Tests (CAT) were used for data gathering purposes. The SPCT was administered by both the investigator and classroom science teachers in each of the high schools, while the results of CAT previously administered by the school district were extracted from student cumulative records.

Science Process Competency Test

As discussed previously in Chapter I, the North Clackamas School District adopted in 1975 a set of eight minimum graduation competencies in science and technological processes. Those minimum competencies were as follows:

". . . 1 The student is able to fit an organism, object or substance into a scientific classification scheme.

". . . 2 The student is able to make laboratory observations and make inferences from these observations.

". . . 3 The student is able to communicate scientific concepts and ideas with the teacher and fellow students.

". . . 4 The student is able to interpret data and make predictions from these interpretations.

". . . 5 The student is able to recognize variables and predict what would happen when selected variables are altered.

". . . 6 The student is able to set up and complete an experiment.

". . .7 The student is able to recognize and use scientific models.

". . .8 The student is able to demonstrate a knowledge of the metric [system] and use common measuring instruments." (North Clackamas School District No. 12 1972, p. [10])

Since there was no standard district-wide procedure for assessing, recording, and/or reporting student progress relative to these competencies, a uniform independent measurement of student performance level was deemed necessary for purposes of this study. In order to gather the desired data with minimum classroom disruption for students and instructional staff, several initial instrument criteria were established. They were as follows:

1. The instrument should restrict itself to measurement of the process skills identified in the North Clackamas School District minimum graduation competencies in science and technological processes

2. The specific process skill performance measured should be restricted to those competencies that are expressed or implied in the district competency statements and sample performance indicators

3. The instrument should be a student self-administered paper and pencil device

4. The instrument should be able to be completed during one fifty-minute class period

An examination of the list of district science and technological processes competencies suggested that not all of them could be assessed under the criteria just enumerated. The investigator determined that a valid measurement of competency 6 would not be possible under the criteria outlined, and it was therefore excluded from the outset.

No existing instrument was identified that fulfilled all of the desired criteria. Therefore the investigator undertook the development of such an instrument.

Additional desirable characteristics of the instrument emerged during the early stages of development. They were as follows:

1. The overall reading level of the instrument should be appropriate for grade nine students

2. The questions contained within the instrument should not be either content or course specific when viewed in terms of the first-level science courses taught in the high schools of the North Clackamas School District

3. The instrument should use multiple choice items exclusively

4. There should be five alternative choices associated with each question stem

5. There should be four questions keyed to each district competency statement retained for purposes of the study

6. To the maximum extent possible, the descriptive contexts of each four-question set should include the biological, physical, earth/space, and general sciences

Characteristic one acknowledged that the youngest subjects included in the study were students in grade nine. Characteristics two, five, and six were desired in order to take into account the diversity of types of science included in first-level science courses without producing questions that favored students enrolled in any particular course. Characteristics three and four provided an acceptable data gathering mode for convenient data management and analysis.

As progress continued on the development of an instrument, a question arose as to the feasibility of being able to obtain a valid measurement of competency 3. It was decided to include the competency in the initial draft and make the final decision after piloting and external validation.

SPCT items

Individual test items were created by the investigator using a variety of resources. First and foremost were the competency statements themselves and their associated sample performance indicators. The sample performance indicators suggested some of the types of behavior students could exhibit in order to demonstrate the minimum acceptable level of performance for each of the competencies. The complete list of competency statements and their sample performance indicators are found in appendix A.

Perusal of a number of secondary and tertiary level texts, teacher's guides, audio-visual materials, and reference books provided additional question ideas. Data used to illustrate situations in item stems were drawn from a number of sources. Table 10 summarizes the references used in item construction. Complete reference information can be found in the Bibliography.

TABLE 10

REFERENCES USED TO DEVELOP SPCT ITEMS

SPCT Question	Competency	Primary Reference Sources
1	1	LaChapelle 1969
2	1	Fish and Wildlife Branch 1980
3	1	Considene 1976
4	1	Williams et al. 1980
5-7	2	General
8	2	Films Inc./Hubbard/V.E.C. 1972
9	4	Steen and Montagu 1959
10-11	4	O'Connor et al. 1973
12	4	Showalter 1978b
13-14	5	General
15	5	Weinberg and Kalish 1971
16	5	Jackson and Evans 1976
17	7	General
18	7	Rutherford et al. 1970
19-20	7	General
21-24	8	General

Pilot testing

An early 28-item draft of the SPCT instrument was piloted with a North Clackamas School District summer school biology class on 20 July 1981. The 19 students present that day ranged in age from 15 to 18, with the majority being 17. Fifty-eight percent of the students attended high school in the North Clackamas School District, and most of the students were enrolled in order to gain the minimum science credit and/or competencies needed to fulfill their graduation requirements.

A limited item analysis of the pilot test results showed a mean raw score of 13.2, standard deviation of 3.7, and K-R 20 reliability of 0.64. Student scores ranged from 5 to 19. The student responses, combined with on-the-spot verbal feedback relative to item clarity, vocabulary, and related matters, were used in further revision of the instrument prior to its submission to an external validation panel.

External validation

The revised pilot instrument was submitted to external validation by a panel of five Oregon science educators. Four members of the panel were from universities within the Oregon State System of Higher Education, and the other from the Oregon Department of Education. The feedback from the validation panel verified the investigator's preliminary suspicion that competency 3 did not lend itself to valid measurement with the type of instrument being used. Competency 3 was therefore deleted from the study. In addition, panel members provided numerous valuable and useful suggestions for improvement of test items, and all of these were incorporated into the final form of the instrument. The panel members expressed 95 percent agreement on the validity of the 24 questions retained for use in the instrument. The validation panel instructions and worksheet are found in appendix D.

Reading level

The reading level of the revised SPCT instrument was determined by the use of the Lorge formula (Lorge 1959). The results of the application of the Lorge formula to each of the SPCT questions are summarized in table 11. The SPCT instructions have a Lorge formula reading level of 6.2. The mean reading level of all SPCT questions is 8.1; the median reading level for all SPCT questions is 7.8.

TABLE 11

SPCT READING LEVEL AS DETERMINED BY THE LORGE FORMULA

Quest. No.	Read. Level	Quest. No.	Read. Level	Quest. No.	Read. Level	Quest. No.	Read. Level
1	9.7	7	7.5	13	7.3	19	8.6
2	6.3	8	7.6	14	7.0	20	9.5
3	8.6	9	7.3	15	8.8	21	8.8
4	7.9	10	7.6	16	9.9	22	8.4
5	5.8	11	10.3	17	8.5	23	7.7
6	6.5	12	10.7	18	7.3	24	7.6

SPCT scoring

The SPCT is designed to be scored by simply counting the number of correct responses. The maximum possible score is 24. There are six SPCT Subtests, each with a maximum possible score of four. These Subtests are Classifying (questions 1-4), Observing (questions 5-8), Interpreting Data (questions 9-12), Identifying Variables (questions 13-16), Modeling (questions 17-20), and Measuring (questions 21-24).

SPCT reliability

Reliability coefficients for the SPCT and its Subtests are presented in table 12. Internal reliability of the revised SPCT was measured by Cronbach's α, which is equivalent to the Kuder-

Richardson formula 20 reliability coefficient since the data were dichotomous (Hull and Nie 1981). Computation of the reliability coefficients for the posttest data of both Sample One (N=690) and Sample Two (N=210) were made by the use of the subprogram RELIABILITY from the Statistical Package for the Social Sciences (SPSS).

The Sample One reliability coefficient of 0.69 and Sample Two reliability coefficient of 0.71 for the overall SPCT show good reliability measures for this type of instrument and reflect the desired stability across the high school grade levels.

The SPCT Subtest reliabilities were quite low, as expected, but they are not unusually low for this type of instrument. The small number of items per Subtest (four) and low levels of student knowledge in some areas (e.g., Modeling) contributed to the low coefficients. The inter-item correlations for the six Subtests were also quite low. At this stage of development, the SPCT total test score appears to be a considerably more robust measure of science process skill competency than the individual Subtests.

A complete copy of the final form of the SPCT is reproduced in appendix E.

TABLE 12

SCIENCE PROCESS COMPETENCY TEST (SPCT) POSTTEST RELIABILITY

SPCT	Sample One Reliability	Sample Two Reliability
Total Test	0.69	0.71
Subtests		
Classifying	0.33	0.14
Observing	0.22	0.23
Interpreting Data	0.46	0.45
Identifying Variables	0.25	0.36
Modeling	0.03	0.19
Measuring	0.41	0.50

California Achievement Tests

High school students who have attended school in the North Clackamas School District since grade seven should have accumulated one or more sets of scores from the California Achievement Tests, Form C, Levels 17-19, published by CTB/McGraw-Hill. The series of test batteries measure achievement in reading vocabulary, reading comprehension, spelling, language mechanics, language expression, mathematics computation, mathematics concepts and applications, and reference skills. Content validity for these basic skills was established by examination of objectives from state and city curriculum guides, texts, and other instructional programs and materials used throughout the United States. Internal reliability was determined by use of the Kuder-Richardson formula 20 (K-R 20) and computation of the standard error of measurement (SEM). Table 13 displays these data for spring testing, which corresponds to the normal testing pattern in the North Clackamas School District.

For purposes of analysis, only the standard total reading, total language, and total mathematics scores were used. When available, the CAT scores selected for inclusion were those identified in table 14. If the desired set of CAT scores was not part of the student's cumulative record, the most recent CAT scores available were selected.

TABLE 13

CALIFORNIA ACHIEVEMENT TESTS RELIABILITY

Test Level and Form	Grade	K-R 20 Reliability			SEM Reliability		
		Reading	Language	Math.	Reading	Language	Math.
17C	7.8	0.95	0.92	0.96	3.54	3.31	3.88
18C	8.8	0.94	0.92	0.96	3.54	3.27	3.79
18C	9.8	0.95	0.93	0.96	3.47	3.21	3.69
19C	10.8	0.95	0.92	0.96	3.52	3.30	3.77

SOURCE; CTB/McGraw-Hill, Technical Bulletin 1, Forms C and D, Levels 10-19, California Achievement Tests (Monterey, CA: CTB/McGraw-Hill, 1979).

TABLE 14

PRIMARY CALIFORNIA ACHIEVEMENT TESTS
SCORES USED IN ANALYSIS OF DATA
FOR SAMPLES ONE AND TWO

Grade	Test Level	Test Form	Administered
9	18	C	April 1981
10	18	C	April 1980
11	19	C	April 1981
12	19	C	April/May 1980

Data Collection Procedures

Data were collected several times during the 1981-82 school year. A portion of the data were obtained by administering the SPCT, another portion from student-completed personal information sheets, and the remainder from student cumulative records.

Pretesting

Building-level arrangements for administering the SPCT as a pretest were made through the individual high school Curriculum Directors. Every effort was made to schedule the pretest for the earliest possible date in the school year in order to minimize the impact of any formal classroom instruction. It was decided to administer the pretest one building at a time rather than simultaneously in all three high schools. This decision was made fundamentally to enable the investigator to be present in the building during testing in order to:

1. Monitor the overall administration of the pretest

2. Respond to any teacher questions that might arise during the day

3. Assure that adequate testing materials were present throughout the testing day

4. Collect and account for all test booklets, Student Information Sheets, and student answer sheets at the end of the testing day

5. Collect information provided by teachers relative to attendance, unusual events or circumstances, and related matters possibly impacting the test results

Once primary building testing dates had been determined and the teachers' contract year had begun, an orientation meeting was scheduled with involved Science Department staff members, the Science Department Coordinator, and the Curriculum Director at Clackamas and Milwaukie High Schools. Individual meetings were held with the same personnel at Rex Putnam High School, since the individuals were already familiar with the general outline of the study. These meetings and individual conferences were held within one week of the scheduled testing dates. During these meetings, an overview of the study was provided, the pretest administrative procedures discussed, and an opportunity provided for perusal of the SPCT itself. A reproduction of one of the information sheets provided those attending the orientation meetings is in appendix C. Appendix C also contains a copy of the Testing Instruction Sheet provided for each participating science teacher in the three high schools.

Sample One pretesting was completed during the period 10-15 September 1981, and make-up testing was completed during the period 14-22 September 1981. The percentages of Sample One students pretested in each school were 95.09 percent at Clackamas High School, 96.23 percent at Milwaukie High School, and 88.89 percent at Rex Putnam High School.

Students marked their answers to the SPCT questions on National Computer Systems Trans-Optic F4521-109876 General Purpose Answer Sheets. The only other information they placed on their answer sheets was the first letter of their last name followed by their birth date. This procedure preserved student anonymity and allowed the personal data from the Student Information Sheets (SIS's) to be transferred to the proper answer sheet.

Student Information Sheets

Each student completed the pretest and a Student Information Sheet (SIS). The SIS contained space for the student to circle or specify a number of different items of a personal nature. Among the information sought were sex, grade level, birth date, science class,

class period, teacher, previous high school science courses, most recent mathematics course completed, junior high school attended, and enrollment information relative to science in grades seven and eight. In cases where the SIS from a student was incomplete or there was a legibility problem, the sheet was returned to the student's classroom teacher along with a request for completion or clarification. Teachers were asked to return the SIS's within one week. In those cases where the SIS's had not been completed or clarified, the investigator checked student cumulative files and/or transcripts in an effort to resolve the difficulties. The investigator also extracted CAT scores from the student cumulative records and recorded them on the SIS for each student. All of the information from the completed SIS was then coded onto the SPCT student answer sheets by the investigator. A copy of a SIS is in appendix F.

Posttesting

As was the case during the pretest arrangements, all posttest details were confirmed through the individual building Curriculum Directors.

Sample One

Teachers of first-level science classes were notified of the exact posttest date by either their building Science Department Coordinator or Curriculum Director approximately one month prior to the designated time. A Posttest Testing Instruction Sheet was delivered to each involved teacher one week prior to the test date.

A copy of this Posttest Testing Instruction Sheet is in appendix C.

The process and procedures used for the posttest were basically the same as those employed on the pretest testing day. The only changes from pretesting were that no SIS was completed, the student responses were marked on a mimeographed response sheet rather than the General Purpose Answer Sheets, and two non-scored information gathering questions were appended to the SPCT. These questions gathered information relative to student perceptions of science they felt they had learned outside of their science class during the school year. Copies of the mimeographed answer sheet and the two appended questions are in appendix F.

Individual buildings were again tested one day at a time, in the same relative order as during pretesting. Posttesting was completed during the period 18-20 May 1982; make-up testing was completed during the period 25-27 May 1982.

A brief Student Information Sheet III (SIS III) was completed by all Sample One students during the period 25-27 May 1982. The SIS III gathered information regarding mathematics classes that the students had been enrolled in during the 1981-82 school year. A copy of the SIS III is in appendix F. The information from the two appended questions to the SPCT and SIS III was coded onto the student answer sheets by the investigator.

Make-up testing was conducted in a similar manner in each of the buildings. On the make-up testing date, students needing to complete the SPCT were sent to a designated location within the building during their regular science class period. The investigator administered the SPCT to these students throughout the day.

Sample One mortality

Overall Sample One mortality was 11.72 percent. The Sample One mortality percentages by school were 7.17 percent for Clackamas, 17.47 percent for Milwaukie, and 10.07 percent for Rex Putnam. Sample One mortality was the combined result of withdrawals from school, dropping of science enrollment, and being transferred from first-level science into an alternative science program. The only severe impact due to this mortality was in the Milwaukie High School tenth-grade Biology group. The number of students remaining in this group was reduced to two; therefore, the group was dropped from further analysis in the study.

The percentages of Sample One students in each school who were not posttested due to absence on the testing dates were 4.91 percent at Clackamas, 3.77 percent at Milwaukie, and 11.11 percent at Rex Putnam. The percentages of the original Sample One students posttested in each school were 87.92 percent at Clackamas, 78.77 percent at Milwaukie, and 78.82 percent at Rex Putnam.

The overall percentage of original Sample One students both pretested and posttested was 81.66 percent (690 students). The number of students in each group of Sample One who were both pretested and posttested is reported in table 15.

Sample Two

As had been the case with Sample One testing, building level arrangements for administering the SPCT to Sample Two students were made through the individual building Curriculum Directors. While the investigator identified the week during which testing was to take place and recommended a date, the final decision was made by the building Curriculum Director. In each building, Sample Two students were tested simultaneously during one of the first three morning class periods.

Arrangements for pre-excusing the students from their regular class during the testing period were made cooperatively through the school attendance staff and the Curriculum Director. Each building notified the instructional staff of the testing date and students involved by means of an internally published memorandum.

At least one week prior to the test date, students in Sample Two received a personal notification of their selection and the testing details. A copy of one of these personalized notices is in appendix F. Sample Two testing was completed during the period 12-18 May 1982.

In all schools, the Sample Two SPCT testing was administered by the investigator with assistance from building personnel. Prior to completing the SPCT, each student completed a personal information sheet. This Student Information Sheet II (SIS II) gathered basically the same information as the pretest SIS used with Sample One students.

A copy of the SIS II is in appendix F. The students marked their SPCT responses on the same type of mimeographed answer sheets as used for Sample One. Both Sample One and Sample Two students responded to the two appended questions to the SPCT. As discussed earlier in this chapter, these questions attempted to determine student perceptions as to science learned outside of science class during the school year. Sample Two student CAT scores were obtained from student cumulative records by the investigator. All SIS II information, the responses to the two appended questions, and CAT scores were coded onto the student answer sheets by the investigator.

CAT Scores

In cases where partial or missing CAT scores were encountered for students in either sample, an effort was made to create a complete set of three CAT scores, as explained in the remainder of this section.

Partial CAT scores

If one or two of the three CAT scores being used were available, the missing score or scores were created by the investigator. The procedure used was straightforward. Mean values for the CAT Reading, CAT Language, and CAT Mathematics scores were calculated for all Sample One students. The CAT percentiles corresponding to these means were also recorded. Correlations between the three CAT scores for each group of students in Sample One were then used to determine, when the option was available, which existing score was to be used to create the missing score. The available score with the highest positive correlation to the missing score was selected. The percentile of the existing score was increased or decreased by the total group percentile difference between the two scores of interest in order to create a percentile for the missing score. An example of such a CAT score creation should help clarify the procedure used.

Situation: A Milwaukie High School ninth-grade Biology student is missing one of three required CAT scores. For illustrative purposes, only percentiles will be shown.

CAT Reading	CAT Language	CAT Mathematics
72	?	68

Step 1: Using CAT score correlations, select the best score from which to create the missing CAT Language score.

CAT Reading and CAT Math	0.7320
CAT Reading and CAT Language	0.7518
CAT Mathematics and CAT Language	0.7681

Since the CAT Mathematics score has the highest positive correlation to CAT Language, it will be used to create the CAT Language score.

Step 2: Adjusting the Cat Mathematics percentile to create a CAT Language percentile.

Total Sample One Mean Percentiles for Grade Nine

CAT Reading	CAT Language	CAT Mathematics
64	58	65

Since the difference between the CAT Mathematics and CAT Language percentiles is -7, the student's CAT Mathematics percentile is lowered by 7 in order to create a CAT Language percentile of 61.

The same procedure was followed for students in Sample Two.

Missing CAT scores

When it was found that CAT scores were missing for a student, but another standardized test set was available and reported in percentiles, those percentiles were used. The created CAT scores were extracted from a CAT "Raw Score To Percentile Rank and Stanine" table for the testing period reported.

Number of created CAT scores

Considering the sample sizes, the number of created CAT scores was quite small. In Sample One, 24 students were assigned one or more created CAT scores, while 22 students had one or more CAT scores created in Sample Two.

Teacher Questionnaire

In order to gather information from teachers relative to their estimate of class time devoted to instruction on the science process skills and any changes in emphasis that may have been implemented during the 1981-82 school year, a Teacher Questionnaire II (TQ II) was completed by first-level science teachers during the period 17-21 May 1982. In addition, TQ II gathered information about inservice or other training experiences that the teachers may have had in the science process skills. A copy of TQ II is found in appendix C.

Statistical Analysis Procedures

Statistical analysis procedures were conducted by use of the computing and data processing facilities of The Ohio State University, North Clackamas School District, and Clackamas County (OR) Education Service District. All useable data were first keypunched by hand. Card accuracy was checked by examination of case listings, perusal of one-way frequency distributions, and for Sample One pretest data, the cross checking of one-way frequency distributions from the keypunched data against one-way frequency distributions produced from electronic scanning of the final coded form of the student answer sheets. The case listings were produced by use of the computing facilities at The Ohio State University and the North Clackamas School District. One-way frequency distributions from cards were generated at The Ohio State University, while those from electronic scanning were produced at the Clackamas County Education Service District.

All data were subjected to analysis by use of programs contained within the Statistical Package for the Social Sciences (SPSS), a system of computer programs designed and developed by a team working initially at Stanford University and later at the National Opinion Research Center at the University of Chicago. The investigator used the second edition of the Statistical Package for the Social Sciences manual (Nie et al. 1975) when employing the SPSS programs.

One-way frequency distributions used for analysis purposes were produced by use of the SPSS subprogram FREQUENCIES. These one-way frequency distributions provided the basic distributional characteristics of the variables included in the study. The statistics selected produced the mean, standard error, median, mode, standard deviation, variance, kurtosis, skewness, range, minimum value, and maximum value for each variable.

The data were next subjected to bivariate correlation analysis, using Pearson product-moment correlation coefficients generated by the SPSS subprogram PEARSON CORR. The available subprogram options selected or defaulted produced output which consisted of the Pearson product-moment correlation coefficient, a two-tailed test of significance, and N. Pairwise deletion was incorporated in the computation of the r values. All supporting statistics options were elected. This resulted in the production of the mean and standard deviation of each variable, as well as the cross-product deviations and covariance. A correlation coefficient matrix that included all variables was produced; a copy of the complete correlation coefficient matrix is available at the ERIC Clearinghouse for Science, Mathematics, and Environmental Education at The Ohio State University, Columbus, Ohio.

The suitable independent variables were then subjected to multiple regression on the SPCT scores by means of the SPSS subprogram REGRESSION. Listwise deletion of missing data was used, and the statistics selected produced a correlation matrix as well as the means, standard deviations, and number of valid cases. An F-test was used to evaluate the significance of the regression equation and the regression coefficients.

The SPSS subprogram ANOVA was used for both analysis of variance (ANOVA) and analysis of covariance (ANCOVA) procedures. The statistics selected resulted in the production of a multiple classification analysis table and the unstandardized partial regression coefficients for the covariates.

Two procedures were used only with the Sample One data. A paired t-test was applied to the pretest and posttest SPCT and SPCT Subscore means for each of the groups included in Sample One. The SPSS subprogram T-TEST was used with pairwise deletion and a one-tailed test of significance.

A rather recent method employed to help assess the educational significance of research findings is to calculate the "effect size," or "delta." It is defined as the difference between two measures expressed in standard deviation units (Glass et al. 1980). In calculating the "delta" values for the pretest/posttest gain of the various groups in Sample One, the unadjusted mean gain of each group was divided by the posttest standard deviation for the group. Thus, $\Delta = \dfrac{\bar{X}_{POST} - \bar{X}_{PRE}}{s_{POST}}$.

One procedure was used only with Sample Two data. Various group means were tested for significant differences by the use of the t-test as conducted by the SPSS subprogram T-TEST. The program performs an F-test of the group variances and provides Student's t, for use with groups whose variances are not significantly different, and an estimate of t, for use with groups that have significantly different variances (Nie et al. 1975, pp. 269-70). Since no significant ($p < .05$) differences in group variances were indicated, Student's t was used with the Sample Two data.

CHAPTER IV

FINDINGS

Introduction

Chapter IV is devoted to a presentation of relevant descriptive statistics, the results of treatment and analysis of the data, testing of hypotheses, and a discussion of the meaning of the data in terms of their statistical and educational significance. Most of the tables in this chapter are reproductions of computer printouts. The abbreviations used for the variables in these tables are found as part of the variables list in appendix G. Brief preliminary sections provide reviews of the composition of the two samples and a listing of the hypotheses tested.

Sample One

Sample One consisted of 356 ninth-grade students and 334 tenth-grade students who were enrolled in first-level science courses at Clackamas, Milwaukie, and Rex Putnam High Schools. Milwaukie High School, however, had only ninth-grade students in the sample. None of the students in Sample One had any prior formal high school science instruction. Sample one students underwent both pretesting and posttesting with the SPCT.

Sample Two

The 210 students in Sample Two were selected at random from their grade level in each of the high schools. Each participating grade level was represented by a group of 30 students; the grade levels eligible for participation were all of those following the one in which science was required in that particular school. Thus, Clackamas and Rex Putnam had students selected from grades 11 and 12, while Milwaukie had students selected from grades 10 through 12.

Hypotheses

The null hypotheses tested are as follows:

1. Academic ability is not a significant variable in accounting for SPCT posttest variance as measured by
   a) Reading achievement
   b) Language achievement
   c) Mathematics achievement
2. Sex is not a significant variable in accounting for SPCT posttest variance
3. Type of science is not a significant variable in accounting for SPCT posttest variance
4. There is no significant difference between the adjusted SPCT posttest means of ninth-grade and tenth-grade students
5. There is no significant difference between the adjusted SPCT posttest means of students who have elected no science after the required year and are one, two, or three years removed from required science

6. There is no significant difference between the adjusted SPCT posttest means of those students who have elected science after the required year and are one, two, or three years removed from required science

7. There is no significant difference between the adjusted SPCT posttest means of students who have elected science after the required and students who have not elected science after the required year

8. There is no significant difference between the adjusteed SPCT posttest means of students who elected science after the required year and students in the same grade level who did not elect science after the required year

9. There is no significant difference between the SPCT pretest/posttest effect size for the different types of science

Results of tests of these hypotheses are reported in this chapter. Discussion of the results is found in the last section of the chapter.

Sample One

Descriptive Statistics

CAT scores

Table 15 presents group mean CAT scores for total reading, total language, and total mathematics. The highest group mean was 60.57 in mathematics, the lowest group mean 48.69 in language, and the means for all Sample One students were 53.91 for reading, 52.44

for language, and 54.53 for mathematics.

For all groups in Sample One, the language mean was the lowest of the three. Five of the eight groups had their highest mean in mathematics, while three of the groups had their highest mean in reading.

The Rex Putnam ninth-grade Unified Science group had the highest set of CAT means, with a total of 175.70. The next highest group, with a total of 167.61, was the Clackamas ninth-grade Physical Science group. These two "select" groups of ninth-grade students are discussed in detail in the next subsection.

Three groups had similar CAT mean totals. These groups were the Rex Putnam tenth-grade Unified Science group with 161.66, the Milwaukie ninth-grade Biology group with 161.49, and the Clackamas tenth-grade Biology group with 159.30. These three groups also were the three largest groups in Sample One, with 165, 135, and 132 students, respectively.

The Milwaukie ninth-grade Integrated Science group had a CAT mean total of 156.05. The Milwaukie ninth-grade Earth and Space Science group, with a CAT mean total of 150.10, and the Clackamas tenth-grade Physical Science group with a CAT mean total of 148.41, had the two lowest sets of CAT mean totals in Sample One.

SPCT pretest

Table 15 presents group SPCT pretest means. The highest group mean was 11.56, the lowest group mean 7.23, and the mean for all

Sample One students was 9.59. The range of the SPCT pretest group means was 4.33.

Since the pretesting of Sample One students was the first use of the revised SPCT instrument, it is not possible to state whether the various group means and overall mean represent higher than expected, lower than expected, or near the expected values for high school students of the ages tested.

The SPCT pretest scores indicated a rather wide range of beginning levels of science process skill knowledge among the various groups. When considering any possible implications of these differences, it is important to keep in mind that the Clackamas and Rex Putnam ninth-grade groups were "selected" students. They exercised a degree of self-selection by electing to enroll in first-level science one year earlier than their peers. In addition, they had to fulfill certain criteria established by their respective high schools. At Clackamas, the students had to make a commitment to enroll in at least one additional year of elective science. At Rex Putnam, a recommendation from their junior high school science teacher was required. Both groups of students, however, were integrated into regular sections of science for instructional purposes. These multiple selection criteria created two groups of relatively high-achieving students. The CAT scores of the Rex Putnam ninth-grade group were the highest of any group in the study, while the Clackamas ninth-grade group had the second highest set of CAT scores. These two groups also had the highest SPCT pretest scores. Similar groups of high achieving ninth-grade students at Milwaukie High School were placed in special single sections of Biology 1-2 and Earth and Space Science 1-2.

After excluding the two high-achieving ninth-grade groups just discussed, a clear pattern that emerged from the data was the higher beginning levels of science process skill knowledge exhibited by tenth-grade students when compared to ninth-grade students. The only exception to this pattern was the Clackamas tenth-grade Physical Science group, that had a slightly lower mean than one of the ninth-grade groups.

SPCT pretest Subtest scores

Table 15 presents SPCT Subtest scores for the pretest. The SPCT contains six Subtests, one for each of the process skill competency areas included in the study. Scores on each Subtest can range from a minimum of zero to a maximum of four. The highest group mean on any Subtest was 2.56 (Interpreting Data); the lowest group mean on any Subtest was 0.66 (Modeling). The pretest total Sample One means for the SPCT Subtests were 1.96 (Classifying), 1.83 (Observing), 2.13 (Interpreting Data), 1.52 (Identifying Variables), 0.75 (Modeling), and 1.40 (Measuring). The grand Sample One student mean for all Subtests was 1.60.

The competency areas of Identifying Variables and Measuring formed a cluster where 88 percent of the group means were between 1 and 2, while the remainder were between 0 and 1. The competency areas of Observing and Classifying formed another cluster, with

75 percent of the group means between 1 and 2, while the remainder were between 2 and 3.

The highest overall set of mean scores was in the competency area of Interpreting Data. Six of the eight groups registered their highest means in this area, while it was the second highest mean area for the remaining two groups. The lowest overall set of mean scores was in the competency area of Modeling. Seven of the eight groups had their lowest means in this competency area. The means for all groups were at about the probability level for guessing.

SPCT posttest

Table 15 presents group SPCT posttest means. The highest group mean was 13.92, the lowest group mean 8.32, the mean for all students 11.61, and the range 5.60.

The Rex Putnam ninth-grade Unified Science group and the Clackamas ninth-grade Physical Science group had the highest posttest means, 13.92 and 13.28, respectively. The Milwaukie ninth-grade Integrated Science group and Milwaukie ninth-grade Earth and Space Science group had the two lowest means in Sample One; these means were 8.32 and 9.85, respectively.

Excluding the "select" Rex Putnam and Clackamas ninth-grade groups, the tenth-grade groups all exhibited higher posttest means than the ninth-grade groups.

SPCT pretest/posttest gain

All groups had a mean gain from the SPCT pretest to posttest. The largest mean gain was 3.24, the smallest mean gain 1.09, the average mean gain for all students 2.02, and the range 2.15.

The largest mean gain was made by the Clackamas tenth-grade Physical Science group, and the smallest mean gain was made by the Milwaukie ninth-grade Integrated Science group. If the two "select" Rex Putnam and Clackamas ninth-grade groups are excluded, the tenth-grade groups all had larger mean gains than the ninth-grade groups.

The Clackamas Physical Science groups and the Rex Putnam Unified Science groups had mean gains of 2.36 to 3.24, which represent all of the mean gains larger than the average Sample One gain.

SPCT Subtests posttest scores

Table 15 presents the posttest scores for the various SPCT Subtests. The highest posttest score on any of the SPCT Subtests was 2.97 on the Interpreting Data Subtest. The lowest posttest score on any of the SPCT Subtests was 0.79 on the Modeling Subtest. The posttest total means for the SPCT Subtests were 2.38 (Classifying), 2.15 (Observing), 2.52 (Interpreting Data), 1.80 (Identifying Variables), 0.99 (Modeling), and 1.73 (Measuring).

On both the Classifying and Interpreting Data Subtests, all groups except the Milwaukie ninth-grade Integrated Science group had means between two and three. The Modeling Subtest, which had the lowest overall posttest mean of any of the Subtests, had only

50 percent of the groups with means greater than 1 and no group had a mean equal to or greater than 2.

The Observing Subtest had half of the groups with means between one and two and the other half had means between two and three. The Identifying Variables and Measuring Subtests both had six groups with means between one and two and the remaining two groups between two and three.

SPCT Subtests pretest/posttest gains

Table 15 presents both the SPCT pretest and posttest scores for each Subtest for each group in Sample One. The largest gain on any Subtest was 0.95 on the Interpreting Data Subtest. The smallest gain on any Subtest was 0.04 on the Modeling Subtest. The average mean gain for all groups across all Subtests was 0.34.

All groups except the Milwaukie ninth-grade Integrated Science group had gains on all Subtests. The Milwaukie group had no change on the Classifying Subtest and had a mean decrease on the Observing Subtest.

Summary

Achievement levels in the basic skill areas of reading, language, and mathematics showed considerable variation between groups. These differences are reported in detail later in this chapter. The two groups that had the highest pretest and posttest SPCT scores were also the two groups that had the highest overall CAT achievement scores.

Generally speaking, tenth-grade students exhibited higher levels of process skill competency prior to their required high school science than did ninth-grade students. However, high achieving ninth-grade students, as measured by CAT scores, displayed the highest pretest scores of any groups in the study.

The competency areas with the highest scores on the pretest administration of the SPCT were Interpreting Data and Classifying, although neither area found all group Subtest means above the 50 percent level. Skills associated with recognizing and using models (Modeling) were at the lowest level of any process skill area on the SPCT pretest, and therefore this area provided the greatest opportunity for growth during the course of the study.

Overall, the SPCT posttest scores increased by 2.02 over the pretest means. The posttest range of 5.60 was greater than the pretest range of 4.33. The Rex Putnam ninth-grade Unified Science and Clackamas ninth-grade Physical Science groups ahd the highest scores on both the pretest and posttest. The Milwaukie ninth-grade Integrated Science group had the lowest scores on both the pretest and posttest. Excluding the two high-achieving Rex Putnam and Clackamas ninth-grade groups, tenth-grade groups had higher posttest scores than the remaining ninth-grade groups.

All groups showed a pretest/posttest mean gain, with the greatest gain by the Clackamas tenth-grade Physical Science group and the smallest by the Milwaukie ninth-grade Integrated Science group.

The Interpreting Data and Classifying Subtests had the highest scores on both the pretest and posttest. The Modeling Subtest remained the lowest area of achievement on both the pretest and posttest.

TABLE 15

MEANS OF SPCT SCORES AND CAT SCORES FOR SAMPLE ONE BY SCHOOL, GRADE LEVEL, AND TYPE OF SCIENCE

Group	N	SPCT		Classify		Observe		Interpret		Variable		Model		Measure		CAT Read	CAT Lang	CAT Math
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post			
CHS 9 PS	64	10.63	13.28	2.52	2.58	1.95	2.45	2.02	2.97	1.72	1.94	0.84	1.27	1.58	2.08	56.45	54.05	57.11
CHS 10 BIO	132	10.19	11.98	2.15	2.51	1.93	2.32	2.28	2.58	1.66	1.89	0.66	0.79	1.51	1.89	53.28	52.60	53.42
CHS 10 PS	37	8.65	11.89	1.76	2.32	1.76	1.97	1.76	2.59	1.32	2.11	0.86	1.19	1.19	1.70	50.28	48.69	49.44
MHS 9 BIO	135	8.80	10.11	1.81	2.21	1.66	1.96	2.00	2.20	1.37	1.51	0.68	0.81	1.28	1.41	53.94	52.99	54.56
MHS 9 E&S	73	8.45	9.85	1.70	2.12	1.62	1.74	1.78	2.21	1.42	1.53	0.89	0.99	1.04	1.26	50.62	49.37	50.11
MHS 9 IS	22	7.23	8.32	1.59	1.59	1.68	1.41	1.59	1.86	0.82	1.00	0.82	0.86	0.73	1.59	53.95	50.20	51.90
RPHS 9 US	62	11.56	13.92	2.37	2.74	2.18	2.45	2.56	2.95	1.79	2.13	0.71	1.35	1.95	2.29	58.97	56.16	60.57
RPHS 10 US	165	9.66	12.17	1.76	2.45	1.84	2.28	2.31	2.61	1.54	1.90	0.77	1.16	1.45	1.76	53.78	52.33	55.55

NOTE: "CHS," "MHS," and "RPHS" identify Clackamas, Milwaukie, and Rex Putnam High Schools, respectively; the science courses Physical Science, Biology, Earth and Space Science, Integrated Science, and Unified Science are identified by "PS," "BIO," "E & S," "IS," and "US," respectively.

Significance of SPCT Pretest/Posttest Gains

The statistical significance of group pretest/posttest gains on the SPCT and its Subtests were evaluated by the application of paired t-tests with one-tailed tests of significance. The results can be found in tables 16-23.

SPCT

All groups showed a significant gain ($p \leq .05$) on the posttest. The only group not at $p < .001$ level of significance was the Milwaukie ninth-grade Integrated Science group. These results were expected, since the district-wide goal that all science courses shared was concerned with the development of science process skill competency in students.

SPCT Subtests

At least half of the groups had significant gains ($p \leq .05$) on all but the Modeling Subtest. Seven of the eight groups in Sample One had significant gains ($p \leq .05$) on the Interpreting Data and Measuring Subtests. Six groups had significant gains ($p \leq .01$) on the Classifying Subtest. Five groups had significant gains ($p \leq .05$) on the Observing Subtest, and four groups had significant gains ($p \leq .05$) on the Identifying Variables Subtest.

Only three groups showed significant gains ($p \leq .05$ on the Modeling Subtest. This was rather surprising, since the Modeling Subtest offered the greatest opportunity for gain based upon pretest results.

Two groups had significant gains ($p \leq .05$) on all six SPCT Subtests. They were the Rex Putnam ninth- and tenth-grade Unified Science groups.

TABLE 16

Sample One Clackamas Ninth-Grade Physical Science SPCT Pretest/Posttest T-Tests

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	T [illegible]LUE
PPROCOMP POSTTEST SPCT SCORE	64	13.2813	3.244	0.405	2.6563	3.183	0.398	[illegible].68**
PROCOMP PRETEST SPCT SCORE		10.6250	3.443	0.430				
PTCLASS	64	2.5781	0.887	0.111	0.0625	0.941	0.118	0.53
CLASSIFY		2.5156	0.854	0.107				
PTOBSV	64	2.4531	0.942	0.118	0.5000	1.309	0.164	3.06*
OBSERVE		1.9531	1.105	0.138				
PTINTERP	64	2.9688	0.975	0.122	0.9531	1.302	0.163	5.85**
INTERP		2.0156	1.215	0.152				
PTVAR	64	1.9375	0.889	0.111	0.2188	1.133	0.142	1.54
VARIABLE		1.7188	1.015	0.127				
PTMODEL	64	1.2656	0.980	0.122	0.4219	1.206	0.151	2.80*
MODEL		0.8438	0.739	0.092				
PTMEASR	64	2.0781	1.074	0.134	0.5000	1.285	0.161	3.11*
MEASURE		1.5781	1.152	0.144				

* $p \leq .005$
** $p < .001$

TABLE 17

Sample One Clackamas Tenth-Grade Biology SPCT Pretest/Posttest T-Tests

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	T VALUE
PPROCOMP POSTTEST SPCT SCORE	132	11.9773	3.533	0.307	1.7879	2.831	0.246	7.26**
PROCOMP PRETEST SPCT SCORE		10.1894	3.133	0.273				
PTCLASS	132	2.5076	0.961	0.084	0.3561	1.106	0.096	3.70**
CLASSIFY		2.1515	0.920	0.080				
PTOBSV	132	2.3182	0.902	0.079	0.3864	1.053	0.092	4.21**
OBSERVE		1.9318	0.974	0.085				
PTINTERP	132	2.5833	1.085	0.094	0.3030	1.223	0.106	2.85*
INTERP		2.2803	1.161	0.101				
PTVAR	132	1.8939	1.065	0.093	0.2348	1.253	0.109	2.15*
VARIABLE		1.6591	1.025	0.089				
PTMODEL	132	0.7879	0.742	0.065	0.1288	0.952	0.083	1.55
MODEL		0.6591	0.675	0.059				
PTMEASR	132	1.8864	1.103	0.096	0.3788	1.149	0.100	3.79**
MEASURE		1.5076	0.992	0.086				

* $p \leq .025$
** $p < .001$

TABLE 18

Sample One Clackamas Tenth-Grade Physical Science SPCT Pretest/Posttest T-Tests

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	T VALUE
PPROCOMP POSTTEST SPCT SCORE	37	11.8919	3.596	0.591	3.2432	3.730	0.613	5.29**
PROCOMP PRETEST SPCT SCORE		8.6486	2.908	0.478				
PTCLASS	37	2.3243	1.002	0.165	0.5676	1.405	0.231	2.46*
CLASSIFY		1.7568	1.038	0.171				
PTOBSV	37	1.9730	1.067	0.175	0.2162	1.397	0.230	0.94
OBSERVE		1.7568	0.983	0.162				
PTINTERP	37	2.5946	1.235	0.203	0.8378	1.772	0.291	2.88*
INTERP		1.7568	1.188	0.195				
PTVAR	37	2.1081	0.936	0.154	0.7838	1.584	0.260	3.01*
VARIABLE		1.3243	1.082	0.178				
PTMODEL	37	1.1892	0.938	0.154	0.3243	1.203	0.198	1.64
MODEL		0.8649	0.918	0.151				
PTMEASR	37	1.7027	0.740	0.122	0.5135	1.193	0.196	2.62*
MEASURE		1.1892	0.908	0.149				

* $p \leq .01$
** $p < .001$

TABLE 19

Sample One Milwaukie Ninth-Grade Biology SPCT Pretest/Posttest T-Tests

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	T VALUE
PPROCOMP	POSTTEST SPCT SCORE							
		10.1111	3.508	0.302				
	135				1.3111	3.123	0.269	4.88**
		8.8000	3.489	0.300				
PROCOMP	PRETEST SPCT SCORE							
PTCLASS								
		2.2074	1.030	0.089				
	135				0.4000	1.265	0.109	3.67**
		1.8074	0.996	0.086				
CLASSIFY								
PTOBSV								
		1.9630	0.965	0.083				
	135				0.3037	1.186	0.102	2.97*
		1.6593	1.009	0.087				
OBSERVE								
PTINTERP								
		2.2000	1.202	0.103				
	135				0.2000	1.392	0.120	1.67*
		2.0000	1.197	0.103				
INTERP								
PTVAR								
		1.5111	1.078	0.093				
	135				0.1407	1.173	0.101	1.39
		1.3704	1.070	0.092				
VARIABLE								
PTMODEL								
		0.8148	0.755	0.065				
	135				0.1333	1.064	0.092	1.46
		0.6815	0.729	0.063				
MODEL								
PTMEASR								
		1.4148	0.933	0.080				
	135				0.1333	1.006	0.087	1.54
		1.2815	0.886	0.076				
MEASURE								

* $p \leq .05$
** $p < .001$

TABLE 20

Sample One Milwaukie Ninth-Grade Earth and Space Science SPCT Pretest/Posttest T-Tests

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	T VALUE
PPROCOMP POSTTEST SPCT SCORE	73	9.8493	3.810	0.446	1.3973	3.040	0.356	3.93**
PROCOMP PRETEST SPCT SCORE		8.4521	3.472	0.406				
PTCLASS	73	2.1233	1.066	0.125	0.4247	1.117	0.131	3.25*
CLASSIFY		1.6986	0.996	0.117				
PTOBSV	73	1.7397	0.972	0.114	0.1233	1.079	0.126	0.98
OBSERVE		1.6164	0.810	0.095				
PTINTERP	73	2.2055	1.213	0.142	0.4247	1.201	0.141	3.02*
INTERP		1.7808	1.057	0.124				
PTVAR	73	1.5342	1.029	0.120	0.1096	1.253	0.147	0.75
VARIABLE		1.4247	1.212	0.142				
PTMODEL	73	0.9863	0.808	0.095	0.0959	1.180	0.138	0.69
MODEL		0.8904	0.718	0.084				
PTMEASR	73	1.2603	1.014	0.119	0.2192	0.866	0.104	2.11*
MEASURE		1.0411	0.920	0.108				

* $p \leq .025$
** $p < .001$

TABLE 21

Sample One Milwaukie Ninth-Grade Integrated Science SPCT Pretest/Posttest T-Tests

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	T VALUE
PPROCOMP POSTTEST SPCT SCORE	22	8.3182	4.005	0.854	1.0909	2.671	0.569	1.92*
PROCOMP PRETEST SPCT SCORE		7.2273	3.394	0.724				
PTCLASS	22	1.5909	1.096	0.234	0.0	1.113	0.237	0.0
CLASSIFY		1.5909	1.054	0.225				
PTOBSV	22	1.4091	1.054	0.225	-0.2727	1.077	0.230	-1.19
OBSERVE		1.6818	0.995	0.212				
PTINTERP	22	1.8636	1.320	0.281	0.2727	1.241	0.265	1.03
INTERP		1.5909	1.368	0.292				
PTVAR	22	1.0000	0.873	0.186	0.1818	0.958	0.204	0.89
VARIABLE		0.8182	0.853	0.182				
PTMODEL	22	0.8636	0.889	0.190	0.0455	0.999	0.213	0.21
MODEL		0.8182	0.795	0.169				
PTMEASR	22	1.5909	1.141	0.243	0.8636	1.082	0.231	3.74**
MEASURE		0.7273	0.703	0.150				

* $p<.05$
** $p<.005$

TABLE 22

Sample One Rex Putnam Ninth-Grade Unified Science SPCT Pretest/Posttest T-Tests

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	T VALUE
PPROCOMP	POSTTEST SPCT SCORE							
		13.9194	3.456	0.439				
	62				2.3548	3.152	0.400	5.88**
		11.5645	3.312	0.421				
PROCOMP	PRETEST SPCT SCORE							
PTCLASS								
		2.7419	0.886	0.113				
	62				0.3710	1.075	0.137	2.72*
		2.3710	0.854	0.108				
CLASSIFY								
PTOBSV								
		2.4516	1.082	0.137				
	62				0.2742	1.190	0.151	1.81*
		2.1774	0.984	0.125				
OBSERVE								
PTINTERP								
		2.9516	1.047	0.133				
	62				0.3871	1.030	0.131	2.96*
		2.5645	1.111	0.141				
INTERP								
PTVAR								
		2.1290	0.966	0.123				
	62				0.3387	1.342	0.170	1.99*
		1.7903	1.103	0.140				
VARIABLE								
PTMODEL								
		1.3548	0.960	0.122				
	62				0.6452	1.175	0.149	4.32**
		0.7097	0.637	0.081				
MODEL								
PTMEASR								
		2.2903	1.165	0.148				
	62				0.3387	1.086	0.138	2.46*
		1.9516	1.108	0.141				
MEASURE								

* $p \leq .05$
** $p < .001$

TABLE 23

Sample One Rex Putnam Tenth-Grade Unified Science SPCT Pretest/Posttest T-Tests

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	T VALUE
PPROCOMP	POSTTEST SPCT SCORE							
		12.1697	3.369	0.262				
	165				2.5091	3.342	0.260	9.65**
		9.6606	3.081	0.240				
PROCOMP	PRETEST SPCT SCORE							
PTCLASS								
		2.4485	0.978	0.076				
	165				0.6909	1.252	0.097	7.09**
		1.7576	1.025	0.080				
CLASSIFY								
PTOBSV								
		2.2848	0.936	0.073				
	165				0.4485	1.232	0.096	4.68**
		1.8364	0.958	0.075				
OBSERVE								
PTINTERP								
		2.6061	0.992	0.077				
	165				0.2970	1.284	0.100	2.97*
		2.3091	1.063	0.083				
INTERP								
PTVAR								
		1.9030	1.031	0.080				
	165				0.3636	1.200	0.093	3.89**
		1.5394	0.985	0.077				
VARIABLE								
PTMODEL								
		1.1636	0.913	0.071				
	165				0.3939	1.188	0.092	4.26**
		0.7697	0.695	0.054				
MODEL								
PTMEASR								
		1.7636	0.949	0.074				
	165				0.3152	0.968	0.075	4.18**
		1.4485	0.978	0.076				
MEASURE								

* $p<.005$
** $p<.001$

Effect Sizes

In order to more fully assess the educational significance of the SPCT pretest/posttest gains of the groups in Sample One, effect sizes or "deltas" (Δ) were calculated. The Δ's were calculated by dividing each group's unadjusted mean gain by its posttest mean standard deviation. The resulting Δ values are found in table 24.

Two of the three largest effect sizes were associated with tenth-grade groups, which is consistent with earlier findings indicating generally greater gains by tenth-grade students. The four largest effect sizes were found in two types of science--physical science and unified science.

The entire battery of effect sizes are generally favorable in magnitude when compared to those reported in the literature. The effect sizes for the two Clackamas Physical Science groups, two Rex Putnam Unified Science groups, and Clackamas tenth-grade Biology group are all larger than the mean effect sizes reported in several meta-analysis studies (El-Nemr 1979; Wise and Okey 1981; Sweitzer 1982).

Since groups with higher pretest scores are put somewhat at a disadvantage (e.g., less opportunity for large mean gains) by the method of effect size computation selected by the investigator, the rather large effect sizes of the Rex Putnam ninth-grade Unified Science group and Clackamas ninth-grade Physical Science group are especially noteworthy. Also worth noting is the Sample One high effect size of 0.90 by the Clackamas tenth-grade Physical Science group. The largest effect size achieved by any of the large groups (e.g., more than 100 students) was the 0.74 of the Rex Putnam tenth-grade Unified Science.

TABLE 24

SAMPLE ONE GROUP EFFECT SIZES BY SCHOOL, GRADE LEVEL, AND TYPE OF SCIENCE

Group	N	Δ
Clackamas 9 Physical Sci.	64	0.82
Clackamas 10 Biology	132	0.51
Clackamas 10 Physical Sci.	37	0.90
Milwaukie 9 Biology	135	0.37
Milwaukie 9 Earth & Space Sci.	73	0.37
Milwaukie 9 Integrated Sci.	22	0.27
Rex Putnam 9 Unified Sci.	62	0.68
Rex Putnam 10 Unified Sci.	165	0.74

Reading Achievement and the SPCT

An examination of the correlations between the lowest reading level SPCT items (2, 5, 6, and 14) and highest reading level SPCT items (1, 11, 12, 16, and 20) and the CAT reading achievement scores showed that reading achievement was a factor, but not to the degree that it prohibited students with lower achievement levels from responding correctly, especially on the lower reading level items.

Additional analysis would be required in order to determine if there was a reading achievement "ceiling effect" for students with lower reading achievement levels.

Summary and possible educational significance

All groups showed a statistically significant gain at $p \leq .05$ on the overall pretest/posttest SPCT scores. The groups had effect sizes ranging from 0.27 to 0.90. These findings are educationally significant, since they indicate that the district's science process skill goal is being addressed to some degree by all of the first-level science courses in the high schools.

However, there are some possible type of science and school differences worthy of further discussion. The Physical Science and Unified Science courses had effect sizes at least 33 percent greater than those in any of the groups representing other types of science. The effect sizes of the three groups from Milwaukie High School were the three lowest effect sizes. However, these two potentially significant differences are confounded by such student variables as grade level, age, sex, and basic skill achievement level, as well as teacher variables. The findings concerning some of these potentially important differences will be found later in this chapter.

No SPCT Subtest had significant ($p \leq .05$) pretest/posttest gains by all groups, and only the Interpreting Data, Measuring, and Classifying Subtests had significant ($p \leq .05$) gains by six or more of the eight groups. It should be noted that this is probably not due to a "ceiling effect" imposed by high pretest scores. The only groups showing significant ($p \leq .05$) gains on all Subtests were the Rex Putnam ninth- and tenth-grade Unified Science groups.

Regression Analysis of SPCT Posttest Variance by Total Sample and Grade Level

Independent variables important in accounting for Sample One SPCT posttest variance were identified by a two-step process. Initially, Pearson product-moment correlation coefficient matrices were generated for each group included in Sample One. All measured variables were included in each matrix. Those variables that had a pattern of significant ($p \leq .05$) correlations with the SPCT posttest scores, SPCT posttest Subtest scores, and/or each other and had meaning in the context of the study, were identified. These variables were then subjected to multiple regression on the total SPCT posttest scores for Sample One and then the SPCT posttest scores for the students in each grade level contained within Sample One.

As a general rule, the regression equations selected for analysis and presentation were those that contained all variables accounting for approximately two percent or more of the variance.

Sample One

Table 25 presents the results of the multiple regression analysis of all Sample One student SPCT posttest scores. There were 15 independent variables entered into the multiple regression procedure. The regression equation contained four significant ($p < .001$) predictor variables that collectively accounted for 53.00 percent of the variance. The equation had an F-value of 186.94 with 4 and 663 degrees of freedom, which was significant at $p < 0.001$.

The most important predictor variable was mathematics achievement, which accounted for 38.39 percent of the variance. The other three variables, in decreasing order of importance, were the SPCT pretest, Milwaukie High School, and reading achievement. Milwaukie High School had a negative regression coefficient.

Removal of the strongest predictor variable, mathematics achievement, from the list of independent variables and repetition of the multiple regression analysis produced an equation that contained three predictor variables. Table 26 presents the results of this multiple regression analysis. These three variables collectively accounted for 48.32 percent of the variance. The equation had an F-value of 206.96 with 3 and 664 degrees of freedom, which was significant at $p < 0.001$.

Following the removal of mathematics achievement, the most important predictor variable was the SPCT pretest. The SPCT pretest accounted for 37.33 percent of the variance. The other two variables were reading achievement and Milwaukie High School, which accounted for 6.50 and 4.50 percent of the variance, respectively. Milwaukie High School again had a negative regression coefficient.

Examination of the combined results of the two multiple regression analyses of Sample One and the simple correlations provides some insight into the relationships among important independent variables. The two most important predictor variables are mathematics achievement and SPCT pretest score. It is clear from the simple correlations and the results of the second multiple regression analysis that mathematics achievement and the SPCT pretest have a high positive correlation with each other.

The entry of reading achievement into the second regression equation and the simple correlations indicate that reading achievement had a high positive correlation with mathematics achievement and the SPCT posttest. Milwaukie High School's increased importance as a predictor variable in the second regression equation reflects its negative correlation with other independent variables that are increasing in importance as predictor variables.

None of the different types of first-level science courses entered either regression equation. This indicates that the achievement level in mathematics and entry level science process skill knowledge, and to a lesser degree level of reading achievement, were more important variables in accounting for science process skill development during the year than was the type of science experienced.

TABLE 25

Total Sample One Multiple Regression of 15 Variables on SPCT Posttest Scores

```
                    MULTIPLE R              0.72804
                    R SQUARE                0.53004
                    ADJUSTED R SQUARE       0.52720
                    STANDARD ERROR          2.57725


ANALYSIS OF VARIANCE        DF     SUM OF SQUARES    MEAN SQUARE         F
REGRESSION                  4.         4966.69578     1241.67394    186.93625
RESIDUAL                  663.         4403.79973        6.64223


   ---------------- VARIABLES IN THE EQUATION ----------------

   VARIABLE            B              BETA       STD ERROR B        F

   CATMATH      0.1382845          0.30670        0.01702       66.038
   PROCOMP      0.3111318          0.28256        0.03880       64.317
   MILHI       -1.687411          -0.21023        0.21893       59.406
   CATREAD      0.8387946D-01      0.17764        0.01731       23.481
   (CONSTANT)  -2.873997


     ------------- VARIABLES NOT IN THE EQUATION -------------

     VARIABLE        BETA IN      PARTIAL     TOLERANCE          F

     CATLANG         0.01280      0.01209      0.41975         0.097
     SEX             0.10583      0.15275      0.97905        15.815
     AGE            -0.04683     -0.05606      0.67351         2.087
     TYPESCI1       -0.02782     -0.03860      0.90450         0.988
     TYPESCI2        0.05406      0.06843      0.75321         3.115
     TYPESCI3        0.05471      0.07628      0.91356         3.874
     TYPESCI4       -0.04445     -0.05887      0.82439         2.302
     GRADE9          0.01020      0.01066      0.51319         0.075
     GRADE10        -0.01020     -0.01066      0.51319         0.075
     CLACKHI         0.03073      0.03820      0.72618         0.967
     PUTHI          -0.03006     -0.03776      0.74161         0.945


                            SUMMARY TABLE

     VARIABLE        MULTIPLE R   R SQUARE   RSQ CHANGE    SIMPLE R

     CATMATH          0.61961     0.38392     0.38392      0.61961
     PROCOMP          0.68828     0.47373     0.08982      0.61094
     MILHI            0.71651     0.51339     0.03966     -0.32691
     CATREAD          0.72804     0.53004     0.01664      0.55537
```

TABLE 26

Total Sample One Multiple Regression of 14 Variables on SPCT Posttest Scores with Mathematics Achievement Removed

```
                   MULTIPLE R            0.69514
                   R SQUARE              0.48323
                   ADJUSTED R SQUARE     0.48089
                   STANDARD ERROR        2.70052


ANALYSIS OF VARIANCE     DF    SUM OF SQUARES    MEAN SQUARE        F
REGRESSION                3.       4528.05858     1509.35286   206.96404
RESIDUAL                664.       4842.43693        7.29263


     --------------- VARIABLES IN THE EQUATION ----------------

     VARIABLE            B               BETA      STD ERROR B         F

     PROCOMP     0.4238795          0.38495          0.03796     124.672
     CATREAD     0.1505266          0.31878          0.01597      86.806
     MILHI       -1.743367         -0.21720          0.22929      57.611
     (CONSTANT)  0.9230668D-02


      ------------- VARIABLES NOT IN THE EQUATION -------------

      VARIABLE       BETA IN      PARTIAL    TOLERANCE          F

      CATLANG        0.10311      0.09696      0.45698      6.292
      SEX            0.08225      0.11362      0.98959      8.702
      AGE           -0.07759     -0.08923      0.68337      5.321
      TYPESCI1      -0.03713     -0.04916      0.90604      1.606
      TYPESCI2       0.02693      0.03510      0.76069      0.818
      TYPESCI3       0.04244      0.05651      0.91619      2.124
      TYPESCI4      -0.00986     -0.01256      0.84155      0.105
      GRADE9         0.03954      0.03960      0.51817      1.041
      GRADE10       -0.03954     -0.03960      0.51817      1.041
      CLACKHI       -0.01021     -0.01226      0.74531      0.100
      PUTHI          0.00892      0.01082      0.75966      0.078


                            SUMMARY TABLE

      VARIABLE         MULTIPLE R   R SQUARE   RSQ CHANGE    SIMPLE R

      PROCOMP             0.61094    0.37325      0.37325     0.61094
      CATREAD             0.66199    0.43823      0.06498     0.55537
      MILHI               0.69514    0.48323      0.04499    -0.32691
```

Sample One ninth-grade students

Table 27 presents the results of a multiple regression analysis of the Sample One ninth-grade SPCT posttest scores. The regression equation contained four predictor variables that collectively accounted for 61.57 percent of the variance. The F-value for the equation was 133.77 with 4 and 334 degrees of freedom, which was significant at $p < 0.001$.

The results were similar to those for the total Sample One analysis. The most important predictor variable was mathematics achievement, which accounted for 47.55 percent of the variance. The other three variables, in decreasing order of importance, were SPCT pretest, Milwaukie High School, and sex. Only Milwaukie High School had a negative regression coefficient. The combination of mathematics achievement and SPCT pretest was a stronger predictor (55.83 percent of the variance) for ninth-grade students than for Sample One as a whole (47.37 percent of the variance).

The removal of the leading predictor, mathematics achievement, from the list of independent variables and repetition of the multiple regression analysis resulted in a regression equation that contained five predictor variables. Table 28 presents the results of the second multiple regression analysis. The five variables collectively accounted for 60.03 percent of the variance. The F-value for the equation was 100.01 with 5 and 333 degrees of freedom, which was significant at $p < 0.001$.

The most important predictor variable was the SPCT pretest, which accounted for 44.66 percent of the variance. The other predictor variables, in decreasing order of importance, were reading achievement, Milwaukie High School, language achievement, and sex. This once again demonstrated the high positive correlation between the SPCT pretest and mathematics achievement. Perhaps the most interesting change, however, was the entry of reading achievement and language achievement into the equation. This lends support to the importance of academic achievement in accounting for SPCT posttest variance. Sex remained in the second equation accounting for about the same amount of variance. This indicates that the sex variable was somewhat independent of academic achievement measures in accounting for posttest variance. The sex variable might have been reflecting science background knowledge, since males at this age are frequently favored in terms of science achievement. As had been the case for the sample as a whole, Milwaukie High School remained in both equations with a negative regression coefficient and increasing strength as a predictor.

For ninth-grade students in Sample One, the majority of the SPCT posttest variance was accounted for by mathematics achievement and the SPCT pretest. None of the four different types of first-level science that were experienced by ninth-grade students entered either of the regression equations.

TABLE 27

Sample One Ninth-Grade Multiple Regression of 13 Variables on SPCT Posttest Scores

```
                              MULTIPLE R           0.78465
                              R SQUARE             0.61568
                              ADJUSTED R SQUARE    0.61108
                              STANDARD ERROR       2.48742


ANALYSIS OF VARIANCE      DF     SUM OF SQUARES    MEAN SQUARE        F
REGRESSION                 4.        3310.63590      827.65896    133.76793
RESIDUAL                 334.        2066.54994        6.18728

       --------------- VARIABLES IN THE EQUATION ----------------

       VARIABLE              B            BETA      STD ERROR B         F

       CATMATH      0.1943456         0.43212         0.02060      88.973
       PROCOMP      0.3278256         0.30012         0.05055      42.052
       MILHI       -1.670270         -0.20234         0.30055      30.885
       SEX          1.103938          0.13785         0.27787      15.783
       (CONSTANT)  -2.136268

         ------------- VARIABLES NOT IN THE EQUATION -------------

         VARIABLE         BETA IN       PARTIAL    TOLERANCE           F

         CATREAD          0.15821       0.16739      0.43021       9.600
         CATLANG          0.16006       0.16802      0.42549       9.674
         AGE             -0.07324      -0.11599      0.96392       4.542
         TYPESCI1        -0.01036      -0.01304      0.60846       0.057
         TYPESCI2         0.05113       0.07464      0.62351       1.876
         TYPESCI3         0.04042       0.05012      0.59096       0.839
         TYPESCI4        -0.06824      -0.09756      0.76565       3.200
         CLACKHI          0.04042       0.05012      0.59096       0.839
         PUTHI           -0.03966      -0.05012      0.61333       0.839

                                 SUMMARY TABLE

         VARIABLE          MULTIPLE R   R SQUARE   RSQ CHANGE     SIMPLE R

         CATMATH              0.68958    0.47552      0.47552      0.68958
         PROCOMP              0.74723    0.55835      0.08283      0.66830
         MILHI                0.77299    0.59752      0.03917     -0.45138
         SEX                  0.78465    0.61568      0.01816      0.18715
```

TABLE 28

Sample One Ninth-Grade Multiple Regression of 12 Variables on SPCT Posttest Scores with Mathematics Achievement Removed

```
                        MULTIPLE R            0.77477
                        R SQUARE              0.60027
                        ADJUSTED R SQUARE     0.59427
                        STANDARD ERROR        2.54062


ANALYSIS OF VARIANCE        DF     SUM OF SQUARES   MEAN SQUARE         F
REGRESSION                   5.        3227.76079     645.55216    100.01227
RESIDUAL                   333.        2149.42505       6.45473


      -------------- VARIABLES IN THE EQUATION ----------------

      VARIABLE            B              BETA      STD ERROR B          F

      PROCOMP      0.3594964           0.32911         0.05122     49.262
      CATREAD      0.88500790D-01      0.18718         0.02704     10.714
      MILHI       -1.911880           -0.23160         0.30466     39.383
      CATLANG      0.1154060           0.22560         0.02620     16.751
      SEX           1.058196           0.13214         0.29269     13.071
      (CONSTANT)  -2.493755


       ----------- VARIABLES NOT IN THE EQUATION ------------

       VARIABLE        BETA IN       PARTIAL    TOLERANCE           F

       AGE            -0.06278      -0.09613      0.93706       3.096
       TYPESCI1        0.00630       0.00780      0.61286       0.020
       TYPESCI2        0.03946       0.05651      0.62500       1.075
       TYPESCI3        0.02241       0.02733      0.59455       0.248
       TYPESCI4       -0.05962      -0.08355      0.70516       2.334
       CLACKHI         0.02241       0.02733      0.59455       0.248
       PUTHI          -0.02200      -0.02733      0.61706       0.248


                               SUMMARY TABLE

       VARIABLE        MULTIPLE R   R SQUARE   RSQ CHANGE    SIMPLE R

       PROCOMP            0.66830    0.44663      0.44663     0.66830
       CATREAD            0.72383    0.52393      0.07729     0.63579
       MILHI              0.75655    0.57237      0.04844    -0.45138
       CATLANG            0.76458    0.58458      0.01221     0.58477
       SEX                0.77477    0.60027      0.01569     0.18715
```

Sample One tenth-grade students

Table 29 presents the results of the multiple regression analysis of Sample One tenth-grade SPCT scores. The regression equation contained three predictor variables that collectively accounted for 40.42 percent of the variance. The F-value for the equation was 73.58 with 3 and 325 degrees of freedom, which was significant at $p < 0.001$.

The most important predictor variable was mathematics achievement, which accounted for 30.53 percent of the SPCT posttest variance. The other two variables were SPCT pretest and reading achievement, which accounted for 7.83 and 2.06 percent of the variance, respectively.

The multiple regression analysis for Sample One tenth-grade students produced the same pair of highest predictor variables as had been the case in earlier regressions on the sample as a whole and on ninth-grade students. The absence of Milwaukie High School as an equation variable is readily explained by the fact that Milwaukie had no tenth-grade students in Sample One.

Summary

The best pair of SPCT posttest predictor variables for the sample as a whole and each of the grade levels included in it was mathematics achievement and SPCT pretest. Mathematics achievement was a slightly more effective predictor than SPCT pretest. The simple correlations and the multiple regression analyses indicated that these two variables had a high positive correlation to each other as well as to the SPCT posttest.

The SPCT posttest variance appeared to be largely accounted for by measures of academic achievement, especially in the areas of mathematics and reading. This was particularly true at the ninth-grade level, where it was possible to account for more than 50 percent of the variance with either the SPCT pretest and mathematics achievement or the SPCT pretest and reading achievement. The regression results suggest that science process skill performance level is enhanced by the possession of high levels of mathematics and reading achievement.

Sex appeared to be a somewhat important variable, operating most strongly at the ninth-grade level. This suggests that whatever sex was reflecting was not as important in the tenth-grade portion of Sample One.

Milwaukie High School's consistent presence in the regression equations when it was on the independent variables list and its constant negative regression coefficient indicate that it had negative correlations with the more important independent variables and the SPCT posttest. These relationships are discussed later in this chapter in the section devoted to analysis of the SPCT posttest variance by school.

TABLE 29

Sample One Tenth-Grade Multiple Regression of
11 Variables on SPCT Posttest Scores

```
                    MULTIPLE R            0.63579
                    R SQUARE              0.40423
                    ADJUSTED R SQUARE     0.39873
                    STANDARD ERROR        2.66623


ANALYSIS OF VARIANCE      DF     SUM OF SQUARES    MEAN SQUARE        F
REGRESSION                 3.        1567.58790      522.52930    73.50465
RESIDUAL                 325.        2310.35739        7.10879

   ---------------- VARIABLES IN THE EQUATION ----------------

   VARIABLE             B              BETA      STD ERROR B        F

   CATMATH       0.1371162          0.30601        0.02455       31.205
   PROCOMP       0.3077743          0.28006        0.05800       28.154
   CATREAD       0.83859700D-01     0.17569        0.02501       11.242
   (CONSTANT)   -2.796927


      ------------ VARIABLES NOT IN THE EQUATION ------------

      VARIABLE         BETA IN       PARTIAL    TOLERANCE          F

      CATLANG         -0.02658      -0.02390     0.48168        0.165
      SEX              0.08517       0.10880     0.97228        3.861
      AGE             -0.03396      -0.04373     0.98806        0.621
      TYPESCI1        -0.02875      -0.03661     0.96627        0.435
      TYPESCI3         0.09242       0.11701     0.95491        4.497
      TYPESCI4        -0.02978      -0.03735     0.93714        0.453
      CLACKHI          0.02978       0.03735     0.93714        0.453
      PUTHI           -0.02910      -0.03660     0.94238        0.434


                              SUMMARY TABLE

      VARIABLE          MULTIPLE R  R SQUARE  RSQ CHANGE    SIMPLE R

      CATMATH             0.55256    0.30532    0.30532      0.55256
      PROCOMP             0.61937    0.38362    0.07830      0.53109
      CATREAD             0.63579    0.40423    0.02061      0.48357
```

School Differences in Academic Achievement

The importance of academic achievement level, especially in the areas of mathematics and reading, to science process skill knowledge became apparent as a result of the examination of correlation coefficients and the completion of the multiple regression analyses. It was therefore appropriate to identify any school differences in student achievement level; one-way analysis of variance (ANOVA) was the procedure used to test for differences.

CAT reading

All possible pairings of the three schools were subjected to one-way ANOVA for CAT reading scores. The results are found in table 30. The ANOVA procedure indicated statistically significant (p .033) differences. Rex Putnam students had significantly higher scores than students at both Clackamas and Milwaukie. No significant ($p \leq .05$) difference was found between the scores of Clackamas and Milwaukie students.

CAT language

All possible pairings of the three schools were subjected to one-way ANOVA for CAT language scores. The results are found in table 31. The ANOVA procedure revealed only one statistically significant ($p=.017$) difference; Rex Putnam students had significantly higher scores than Milwaukie students.

CAT mathematics

All possible pairings of the three schools were subjected to one-way ANOVA for CAT mathematics scores. The results are found in table 32. The ANOVA procedure indicated that Rex Putnam students had significantly ($p < .001$) higher scores than Clackamas and Milwaukie students.

Summary

Rex Putnam High School students were found to have had significantly ($p \leq .033$) higher CAT mathematics and reading scores than their counterparts at Clackamas and Milwaukie High Schools. In the CAT language scores, Rex Putnam students were found to have had significantly ($p = .017$) higher scores than students at Milwaukie. The reader is reminded that the CAT scores used for analysis were eighth-grade scores.

TABLE 30

Total Sample One Analysis of Variance of Student CAT Reading Scores by School

CLACKAMAS VS MILWAUKIE

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	64.627	1	64.627	1.010	0.315
ID	64.627	1	64.627	1.010	0.315
EXPLAINED	64.629	1	64.629	1.010	0.315
RESIDUAL	28334.387	443	63.960		
TOTAL	28399.016	444	63.962		

MILWAUKIE VS PUTNAM

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	563.651	1	563.651	8.487	0.004
ID	563.651	1	563.651	8.487	0.004
EXPLAINED	563.652	1	563.652	8.487	0.004
RESIDUAL	28891.148	435	66.416		
TOTAL	29454.801	436	67.557		

CLACKAMAS VS PUTNAM

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	258.421	1	258.421	4.554	0.033
ID	258.421	1	258.421	4.554	0.033
EXPLAINED	258.422	1	258.422	4.554	0.033
RESIDUAL	25650.328	452	56.749		
TOTAL	25908.750	453	57.194		

TABLE 31

Total Sample One Analysis of Variance of
Student CAT Language Scores by School

CLACKAMAS VS MILWAUKIE

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	64.688	1	64.688	1.122	0.290
ID	64.688	1	64.688	1.122	0.290
EXPLAINED	64.691	1	64.691	1.122	0.290
RESIDUAL	25552.254	443	57.680		
TOTAL	25616.945	444	57.696		

MILWAUKIE VS PUTNAM

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	334.560	1	334.560	5.690	0.017
ID	334.560	1	334.560	5.690	0.017
EXPLAINED	334.563	1	334.563	5.690	0.017
RESIDUAL	25577.754	435	58.799		
TOTAL	25912.316	436	59.432		

CLACKAMAS VS PUTNAM

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	110.585	1	110.585	2.282	0.132
ID	110.585	1	110.585	2.282	0.132
EXPLAINED	110.586	1	110.586	2.282	0.132
RESIDUAL	21903.055	452	48.458		
TOTAL	22013.641	453	48.595		

TABLE 32

Total Sample One Analysis of Variance of Student CAT Mathematics Scores by School

CLACKAMAS VS MILWAUKIE

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	83.035	1	83.035	1.252	0.264
ID	83.035	1	83.035	1.252	0.264
EXPLAINED	83.035	1	83.035	1.252	0.264
RESIDUAL	29379.609	443	66.320		
TOTAL	29462.645	444	66.357		

MILWAUKIE VS PUTNAM

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	1717.528	1	1717.528	24.090	0.000
ID	1717.528	1	1717.528	24.090	0.000
EXPLAINED	1717.531	1	1717.531	24.090	0.000
RESIDUAL	31013.629	435	71.296		
TOTAL	32731.160	436	75.071		

CLACKAMAS VS PUTNAM

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	1091.280	1	1091.280	17.649	0.000
ID	1091.280	1	1091.280	17.649	0.000
EXPLAINED	1091.281	1	1091.281	17.649	0.000
RESIDUAL	27948.711	452	61.833		
TOTAL	29039.992	453	64.106		

Regression Analysis of SPCT Posttest Variance by School

Similarities and differences in the ways in which SPCT posttest variance were accounted for within individual schools were assessed by means of multiple regression analysis. The list of independent variables entered into the regression was the same as for earlier regressions of the total Sample One student SPCT posttest scores, being modified only to the extent that it be rendered appropriate for each participating school. The regression equations selected for presentation and discussion were the ones that included all independent variables accounting for approximately two percent or more of the variance.

Clackamas High School

Table 33 presents the results of the multiple regression analysis of Sample One Clackamas High School student SPCT posttest scores. The regression equation contained two predictor variables that together accounted for 48.12 percent of the variance. The F-value for the equation was 105.74 with 2 and 228 degrees of freedom, which was significant at $p < 0.001$.

The most important predictor variable was mathematics achievement, which accounted for 42.12 percent of the variance; the SPCT pretest accounted for 6.00 percent of the variance.

Removal of the SPCT pretest from the list of independent variables and repetition of the multiple regression procedure resulted in an equation containing three predictor variables that collectively accounted for 46.32 percent of the variance. The results of the second regression analysis of the Sample One Clackamas High School student SPCT posttest scores are found in table 34. The F-value for the equation was 65.29 with 3 and 227 degrees of freedom, which was significant at $p < 0.001$.

Mathematics achievement remained the primary predictor variable, accounting for 42.12 percent of the variance. The other two variables were reading achievement and sex, accounting for 2.77 and 1.43 percent of the variance, respectively. Males had significantly higher SPCT scores than females.

TABLE 33

Sample One Clackamas High School Multiple Regression of Ten Variables on Student SPCT Posttest Scores

```
                    MULTIPLE R             0.69370
                    R SQUARE               0.48122
                    ADJUSTED R SQUARE      0.47666
                    STANDARD ERROR         2.51700

ANALYSIS OF VARIANCE      DF      SUM OF SQUARES    MEAN SQUARE        F
REGRESSION                 2.         1339.84602      669.92301    105.74448
RESIDUAL                 228.         1444.44835        6.33530

   --------------- VARIABLES IN THE EQUATION ---------------

   VARIABLE            B               BETA     STD ERROR B        F

   CATMATH     0.2159307          0.46940       0.02721       62.993
   PROCOMP     0.3249717          0.30377       0.06327       26.381
   (CONSTANT)  -2.573810

     ------------ VARIABLES NOT IN THE EQUATION ------------

     VARIABLE       BETA IN      PARTIAL    TOLERANCE          F

     CATREAD        0.14686      0.14490      0.50506        4.869
     CATLANG        0.06244      0.06124      0.49901        0.854
     SEX            0.08556      0.11765      0.98078        3.186
     AGE           -0.01367     -0.01836      0.93623        0.077
     TYPESCI1      -0.08608     -0.11872      0.98068        3.245
     TYPESCI3       0.08608      0.11872      0.98068        3.245
     GRADE9         0.01363      0.01819      0.92293        0.075
     GRADE10       -0.01363     -0.01819      0.92293        0.075

                            SUMMARY TABLE

     VARIABLE         MULTIPLE R   R SQUARE   RSQ CHANGE    SIMPLE R

     CATMATH            0.64899     0.42119     0.42119      0.64899
     PROCOMP            0.69370     0.48122     0.06003      0.58128
```

TABLE 34

Sample One Clackamas High School Multiple Regression of Nine Variables on Student SPCT Posttest Scores with Pretest Removed

```
                        MULTIPLE R            0.68059
                        R SQUARE              0.46320
                        ADJUSTED R SQUARE     0.45611
                        STANDARD ERROR        2.56597


ANALYSIS OF VARIANCE     DF     SUM OF SQUARES    MEAN SQUARE        F
REGRESSION               3.       1289.68595       429.89532     65.29218
RESIDUAL               227.       1494.60842         6.58418

     --------------- VARIABLES IN THE EQUATION -----------------

     VARIABLE           B             BETA      STD ERROR B        F

     CATMATH      0.2306413         0.50138       0.03033        57.819
     CATREAD      0.1096567         0.23278       0.03108        12.448
     SEX          0.8352231         0.12026       0.33915         6.065
     (CONSTANT)  -6.407761


       ------------ VARIABLES NOT IN THE EQUATION -------------

       VARIABLE       BETA IN      PARTIAL     TOLERANCE         F

       CATLANG        0.08634      0.07439      0.39852        1.258
       AGE           -0.00276     -0.00365      0.93386        0.003
       TYPESCI1      -0.04146     -0.05599      0.97905        0.711
       TYPESCI3       0.04146      0.05599      0.97905        0.711
       GRADE9        -0.03055     -0.03980      0.91104        0.359
       GRADE10        0.03055      0.03980      0.91104        0.359


                             SUMMARY TABLE

       VARIABLE         MULTIPLE R  R SQUARE  RSQ CHANGE   SIMPLE R

       CATMATH            0.64899    0.42119    0.42119     0.64899
       CATREAD            0.66997    0.44886    0.02767     0.56081
       SEX                0.68059    0.46320    0.01434     0.06036
```

Milwaukie High School

Table 35 presents the results of the multiple regression analysis of Sample One Milwaukie High School student SPCT posttest scores. The regression equation contained four predictor variables that collectively accounted for 56.79 percent of the variance. The F-value for the equation was 68.67 with 4 and 209 degrees of freedom, which was significant at $p < 0.001$.

The most important predictor variable was mathematics achievement, which accounted for 42.95 percent of the variance. The other predictor variables, in decreasing order of importance, were SPCT pretest, language achievement, and sex. Males had significantly higher SPCT scores than females. The reader is reminded that all Milwaukie High School students in Sample One are ninth-grade students.

Removal of the SPCT pretest from the list of independent variables and repetition of the multiple regression procedure produced a new set of four variables that collectively accounted for 51.95 percent of the variance. The results of this second regression analysis of Sample One Milwaukie High School student SPCT posttest scores are found in table 36. The F-value for the equation was 56.49 with 4 and 209 degrees of freedom, which was significant at $p < 0.001$.

Mathematics achievement remained the most important predictor variable, accounting for 42.95 percent of the variance. The other three predictor variables, in decreasing order of importance, were reading achievement, sex, and Integrated Science. The entry of Integrated Science into the equation was meaningful, even though it accounted for only 1.65 percent of the variance. This was the first instance in the analysis of Sample One data where any type of science entered a regression equation. Integrated Science had a negative regression coefficient, and its entry into the equation with removal of the SPCT pretest was a reflection of the very low pretest and posttest scores of the Integrated Science students at Milwaukie High School.

TABLE 35

Sample One Milwaukie High School Multiple Regression of Nine Variables on Student SPCT Posttest Scores

```
                    MULTIPLE R            0.75359
                    R SQUARE              0.56790
                    ADJUSTED R SQUARE     0.55963
                    STANDARD ERROR        2.43912

ANALYSIS OF VARIANCE      DF     SUM OF SQUARES    MEAN SQUARE        F
REGRESSION                4.         1634.19060      408.54765   68.67160
RESIDUAL                209.         1243.40286        5.94930

      -------------- VARIABLES IN THE EQUATION ----------------

      VARIABLE          B             BETA     STD ERROR B          F

      CATMATH     0.1023494        0.24301        0.03250         9.920
      PROCCMP     0.3406529        0.32179        0.06344        28.835
      CATLANG     0.1249161        0.28150        0.03196        15.279
      SEX          1.102224        0.15019        0.34202        10.386
      (CONSTANT)  -5.493414

        ----------- VARIABLES NOT IN THE EQUATION -------------

        VARIABLE       BETA IN      PARTIAL    TOLERANCE          F

        CATREAD        0.09882      0.08630      0.32957       1.561
        AGE           -0.09803     -0.14369      0.92823       4.385
        TYPESCI1      -0.02151     -0.03141      0.92112       0.205
        TYPESCI2       0.07102      0.10434      0.93260       2.289
        TYPESCI4      -0.07388     -0.11043      0.96556       2.568

                            SUMMARY TABLE

        VARIABLE          MULTIPLE R  R SQUARE  RSQ CHANGE   SIMPLE R

        CATMATH              0.65538   0.42953     0.42953    0.65538
        PROCCMP              0.72119   0.52012     0.09059    0.64485
        CATLANG              0.73921   0.54643     0.02651    0.63039
        SEX                  0.75359   0.56790     0.02147    0.15814
```

TABLE 36

Sample One Milwaukie High School Multiple Regression of
Eight Variables on Student SPCT Posttest Scores
with Pretest Removed

```
                         MULTIPLE R           0.72076
                         R SQUARE             0.51950
                         ADJUSTED R SQUARE    0.51031
                         STANDARD ERROR       2.57210


ANALYSIS OF VARIANCE      DF    SUM OF SQUARES   MEAN SQUARE       F
REGRESSICN                 4.       1494.91477     373.72869   56.49129
RESIDUAL                 209.       1382.67869       6.61569

    -------------- VARIABLES IN THE EQUATION ---------------

    VARIABLE           B            BETA      STD ERRCR B       F

    CATMATH     0.1831443        0.43485        0.02937     38.894
    CATREAD     0.1314650        0.30793        0.02983     19.425
    SEX          1.213294        0.16532        0.35770     11.505
    TYPESCI4    -1.637169       -0.12995        0.61053      7.191
    (CONSTANT)  -7.259866


      ----------- VARIABLES NOT IN THE EQUATION -----------

      VARIABLE      BETA IN      PARTIAL   TOLERANCE         F

      CATLANG       0.21645      0.16893     0.29265       6.110
      AGE          -0.10455     -0.14717     0.95211       4.605
      TYPESCI1     -0.08154     -0.10417     0.78413       2.282
      TYPESCI2      0.07664      0.10417     0.88777       2.282


                          SUMMARY TABLE

      VARIABLE         MULTIPLE R  R SQUARE  RSQ CHANGE   SIMPLE R

      CATMATH            0.65538    0.42953    0.42953    0.65538
      CATREAD            0.69312    0.48042    0.05089    0.62774
      SEX                0.70920    0.50297    0.02255    0.15814
      TYPESCI4           0.72076    0.51950    0.01653   -0.11591
```

Rex Putnam High School

Table 37 presents the results of the multiple regression analysis of Sample One Rex Putnam High School student SPCT posttest scores. The regression equation contained four predictor variables that collectively accounted for 40.46 percent of the variance. The F-value for the equation was 37.04 with 4 and 218 degrees of freedom, which was significant at $p < 0.001$.

The most important predictor variable was mathematics achievement, which accounted for 29.59 percent of the variance. The other predictor variables, in decreasing order of importance, were SPCT pretest, reading achievement, and sex. Males had significantly higher scores than females.

Removal of the SPCT pretest from the list of independent variables and repetition of the multiple regression procedure resulted in no new variables entering the equation. Table 38 contains the results of this second regression analysis of the Sample One Rex Putnam High School student SPCT posttest scores. The F-value for the equation was 42.34 with 3 and 219 degrees of freedom, which was significant at $p < 0.001$.

The three remaining variables collectively accounted for 36.71 percent of the variance. Mathematics achievement remained the most important predictor variable, accounting for 29.59 percent of the variance; the other two variables were reading achievement and sex. Males had significantly higher scores than females.

Summary

For each school, a regression equation was included that had the SPCT pretest removed as a predictor variable. There are two benefits derived from this procedure. First, it provides equations able to be used in the three high schools without the requirement of a SPCT pretest score. In addition, the removal of the SPCT pretest provides an analysis of the contribution of variables other than prior knowledge of the science process skills to explaining the variance in SPCT posttest scores.

The schools demonstrated great similarity in variables entered into the regression equations. In each school, the first two predictor variables were the same. Mathematics achievement was the strongest predictor, accounting for from 29.59 to 42.95 percent of the variance. SPCT pretest was the next most important predictor variable, accounting for an additional 6.00 to 9.06 percent of the variance.

Sex was a variable that entered into two of the three school equations. It accounted for 2.15 percent of the variance at Milwaukie High School and 1.58 percent of the variance at Rex Putnam High School. Males scored significantly higher than females.

Other variables that entered at least one of the school equations were language achievement and reading achievement. Language achievement accounted for 2.63 percent of the variance at Milwaukie High School and reading achievement accounted for 2.00 percent of the variance at Rex Putnam High School.

The most noticeable difference between the schools was the considerably larger amount of variance able to have been accounted for at Milwaukie High School. The Milwaukie regression equation accounted for 16.33 percent more variance than the Rex Putnam equation, and 8.67 percent more variance than the Clackamas equation.

As was the case with all of the other regression equations in the analysis of Sample One data, grade level did not emerge as an important predictor variable. The only type of science to be included in any equation (the second Milwaukie High School equation) was Integrated Science. Integrated Science had a negative regression coefficient and accounted for only 1.65 percent of the variance.

TABLE 37

Sample One Rex Putnam High School Multiple Regression of Eight Variables on Student SPCT Posttest Scores

```
                         MULTIPLE R            0.63611
                         R SQUARE              0.40463
                         ADJUSTED R SQUARE     0.39371
                         STANDARD ERROR        2.71165


ANALYSIS OF VARIANCE       DF     SUM OF SQUARES    MEAN SQUARE         F
REGRESSION                 4.       1089.42859       272.35715     37.04000
RESIDUAL                 218.       1602.96603         7.35306


   --------------- VARIABLES IN THE EQUATION ----------------

   VARIABLE             B           BETA     STD ERROR B        F

   CATMATH     0.1325095         0.31059       0.02867     21.356
   PROCOMP     0.2652925         0.24939       0.07157     13.740
   CATREAD     0.8156194D-01     0.17994       0.02964      7.572
   SEX         0.8783177         0.12633       0.36568      5.769
   (CONSTANT)  -2.494337


      ----------- VARIABLES NOT IN THE EQUATION -----------

      VARIABLE        BETA IN      PARTIAL    TOLERANCE        F

      CATLANG        -0.06203     -0.05565     0.47917       0.674
      AGE            -0.04093     -0.05060     0.91014       0.557
      GRADE9         -0.00906     -0.01083     0.85095       0.025
      GRADE10         0.00906      0.01083     0.85095       0.025

                            SUMMARY TABLE

      VARIABLE        MULTIPLE R  R SQUARE  RSQ CHANGE   SIMPLE R

      CATMATH          0.54393    0.29586    0.29586     0.54393
      PROCOMP          0.60732    0.36884    0.07298     0.52904
      CATREAD          0.62360    0.38888    0.02003     0.47802
      SEX              0.63611    0.40463    0.01576     0.14045
```

TABLE 38

Sample One Rex Putnam High School Multiple Regression of Seven Variables on Student SPCT Posttest Scores with Pretest Removed

```
                        MULTIPLE R            0.60589
                        R SQUARE              0.36711
                        ADJUSTED R SQUARE     0.35844
                        STANDARD ERROR        2.78941


ANALYSIS CF VARIANCE       DF     SUM OF SQUARES    MEAN SQUARE          F
REGRESSICN                 3.          988.39408      329.46469     42.34316
RESIDUAL                 219.         1704.00054        7.78082


   --------------- VARIABLES IN THE EQUATION ----------------

   VARIABLE           B            BETA      STD ERRCR B         F

   CATMATH     0.1743684        0.40870        0.02711       41.362
   CATREAD     0.1176476        0.25955        0.02880       16.688
   SEX          1.026359        0.14762        0.37392        7.534
   (CONSTANT)  -4.235522


     ------------ VARIABLES NOT IN THE EQUATION -------------

     VARIABLE       BETA IN      PARTIAL    TOLERANCE          F

     CATLANG       -0.00433     -0.00384      0.49942      0.003
     AGE           -0.05433     -0.06530      0.91426      0.934
     GRADE9         0.00295      0.00342      0.85374      0.003
     GRADE10       -0.00295     -0.00342      0.85374      0.003


                               SUMMARY TABLE

     VARIABLE         MULTIPLE R   R SQUARE   RSQ CHANGE   SIMPLE R

     CATMATH            0.54393    0.29586     0.29586     0.54393
     CATREAD            0.58765    0.34533     0.04947     0.47802
     SEX                0.60589    0.36711     0.02177     0.14045
```

School and Grade Level SPCT Posttest Differences

An analysis of covariance (ANCOVA) technique was used in order to assess any school or grade level SPCT posttest differences that existed after adjusting for important variables.

School differences

Table 39 presents the ANCOVA results for school differences. The ANCOVA was conducted on Sample One SPCT posttest scores by school with mathematics achievement, SPCT pretest, reading achievement, sex, and age as covariates. The ANCOVA indicated one or more significant ($p < .001$) school differences.

In order to determine between which schools the significant differences existed, the ANCOVA procedure was performed between all possible pairings of schools. The results of these ANCOVA procedures are presented in tables 40 through 42. The ANCOVA comparisons indicated no significant difference ($p \leq .05$) between Clackamas and Rex Putnam High School adjusted student SPCT posttest means. Both Clackamas and Rex Putnam students had significantly ($p < .001$) higher adjusted SPCT posttest means than Milwaukie High School students.

Grade level differences

Table 43 presents the ANCOVA results for the comparison of Sample One ninth-grade and tenth-grade SPCT posttest scores. The ANCOVA was conducted on the SPCT posttest scores by grade level with mathematics achievement, SPCT pretest, reading achievement, sex, and age as covariates. The ANCOVA indicated a significant ($p < .001$) difference; tenth-grade students had significantly higher scores.

TABLE 39

Sample One Analysis of Covariance of Student SPCT Posttest Scores by School with Mathematics Achievement, SPCT Pretest, Reading Achievement, Sex, and Age as Covariates

```
                      SUM OF             MEAN               SIGNIF
SOURCE OF VARIATION  SQUARES   DF      SQUARE         F      OF F

COVARIATES          4719.887    5     943.977   145.670     0.000
   PROCOMP           495.049    1     495.049    76.394     0.000
   CATMATH           528.574    1     528.574    81.567     0.000
   CATREAD           148.795    1     148.795    22.961     0.000
   AGE                59.433    1      59.433     9.171     0.003
   SEX                85.792    1      85.792    13.239     0.000

MAIN EFFECTS         372.883    2     186.441    28.771     0.000
   ID                372.883    2     186.441    28.771     0.000

EXPLAINED           5092.770    7     727.538   112.270     0.000

RESIDUAL            4276.957  660       6.480

TOTAL               9369.727  667      14.048




GRAND MEAN =     11.66                              ADJUSTED FOR
                                                    INDEPENDENTS
                                      UNADJUSTED   + COVARIATES
VARIABLE + CATEGORY          N        DEV'N   ETA   DEV'N   BETA

ID
     1 CLACKAMAS           231         0.66           0.74
     2 MILWAUKIE           214        -1.78          -1.33
     3 PUTNAM              223         1.02           0.51
                                               0.33            0.24

MULTIPLE R SQUARED                                            0.544
MULTIPLE R                                                    0.737
```

TABLE 40

Sample One Clackamas High School and Milwaukie High School
Analysis of Covariance of Student SPCT Posttest Scores
by School with Mathematics Achievement, SPCT Pretest,
Reading Achievement, Sex, and Age as Covariates

```
                          SUM OF             MEAN               SIGNIF
SOURCE OF VARIATION      SQUARES     DF     SQUARE        F       OF F

COVARIATES              3360.599      5    672.120  110.529      0.000
   PROCOMP               378.951      1    378.951   62.318      0.000
   CATMATH               311.131      1    311.131   51.165      0.000
   CATREAD                85.039      1     85.039   13.985      0.000
   AGE                    56.215      1     56.215    9.245      0.003
   SEX                    50.299      1     50.299    8.272      0.004

MAIN EFFECTS             302.424      1    302.424   49.733      0.000
   ID                    302.424      1    302.424   49.733      0.000

EXPLAINED               3663.022      6    610.504  100.396      0.000

RESIDUAL                2663.450    438      6.081

TOTAL                   6326.473    444     14.249




GRAND MEAN =    11.14                              ADJUSTED FOR
                                                   INDEPENDENTS
                                     UNADJUSTED    + COVARIATES
VARIABLE + CATEGORY          N       DEV'N   ETA   DEV'N    BETA

ID
    1 CLACKAMAS            231       1.18            1.00
    2 MILWAUKIE            214      -1.27           -1.08
                                             0.32             0.28

MULTIPLE R SQUARED                                            0.579
MULTIPLE R                                                    0.761
```

TABLE 41

Sample One Milwaukie High School and Rex Putnam High School
Analysis of Covariance of Student SPCT Posttest Scores
by School with Mathematics Achievement, SPCT Pretest,
Reading Achievement, Sex, and Age as Covariates

```
                          SUM OF               MEAN                SIGNIF
SOURCE OF VARIATION       SQUARES     DF      SQUARE        F        OF F

COVARIATES               3306.412      5     661.282     99.302     0.000
   PROCOMP                314.208      1     314.208     47.183     0.000
   CATMATH                357.464      1     357.464     53.679     0.000
   CATREAD                112.383      1     112.383     16.876     0.000
   AGE                     35.681      1      35.681      5.358     0.021
   SEX                     65.063      1      65.063      9.770     0.002

MAIN EFFECTS              260.619      1     260.619     39.136     0.000
   ID                     260.619      1     260.619     39.136     0.000

EXPLAINED                3567.031      6     594.505     89.274     0.000

RESIDUAL                 2863.515    430       6.659

TOTAL                    6430.547    436      14.749




GRAND MEAN =     11.31                                   ADJUSTED FOR
                                                         INDEPENDENTS
                                          UNADJUSTED    + COVARIATES
VARIABLE + CATEGORY            N          DEV'N   ETA    DEV'N    BETA

ID
     2 MILWAUKIE             214          -1.43          -1.02
     3 PUTNAM                223           1.37           0.98
                                                  0.37             0.26

MULTIPLE R SQUARED                                                0.555
MULTIPLE R                                                        0.745
```

TABLE 42

Sample One Clackamas High School and Rex Putnam High School Analysis of Covariance of Student SPCT Posttest Scores by School with Mathematics Achievement, SPCT Pretest, Reading Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	2476.110	5	495.222	73.585	0.000
PROCOMP	217.194	1	217.194	32.273	0.000
CATMATH	345.375	1	345.375	51.319	0.000
CATREAD	95.209	1	95.209	14.147	0.000
AGE	2.983	1	2.983	0.443	0.506
SEX	64.553	1	64.553	9.592	0.002
MAIN EFFECTS	6.803	1	6.803	1.011	0.315
ID	6.804	1	6.804	1.011	0.315
EXPLAINED	2482.913	6	413.819	61.489	0.000
RESIDUAL	3008.298	447	6.730		
TOTAL	5491.211	453	12.122		

GRAND MEAN = 12.50

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
ID					
1 CLACKAMAS	231	-0.18		0.12	
3 PUTNAM	223	0.18		-0.13	
			0.05		0.04
MULTIPLE R SQUARED					0.452
MULTIPLE R					0.672

TABLE 43

Sample One Analysis of Covariance of Student SPCT Posttest Scores by Grade Level with Mathematics Achievement, SPCT Pretest, Reading Achievement, Sex, and Age as Covariates

```
                          SUM OF               MEAN               SIGNIF
SOURCE OF VARIATION      SQUARES     DF      SQUARE        F       OF F

COVARIATES              4719.887      5     943.977  139.508     0.000
   PROCOMP               495.049      1     495.049   73.162     0.000
   CATMATH               528.574      1     528.574   78.117     0.000
   CATREAD               148.795      1     148.795   21.990     0.000
   AGE                    59.433      1      59.433    8.783     0.003
   SEX                    85.792      1      85.792   12.679     0.000

MAIN EFFECTS             177.215      1     177.215   26.190     0.000
   YEAR                  177.216      1     177.216   26.190     0.000

EXPLAINED               4897.102      6     816.184  120.622     0.000

RESIDUAL                4472.625    661       6.766

TOTAL                   9369.727    667      14.048




GRAND MEAN =     11.66                                  ADJUSTED FOR
                                                        INDEPENDENTS
                                          UNADJUSTED    + COVARIATES
VARIABLE + CATEGORY             N         DEV'N   ETA   DEV'N   BETA

YEAR
     1 GRADE 9                339         -0.41         -0.83
     2 GRADE 10               329          0.42          0.85
                                                 0.11            0.22

MULTIPLE R SQUARED                                               0.523
MULTIPLE R                                                       0.723
```

First-Level Science Instruction
Teacher Questionnaire Results

Teachers of first-level science courses in each building responded to Teacher Questionnaire II (a copy is found in appendix C) near the end of the 1981-82 school year. The information provided by the teachers was concerned with the process skill component of instruction and their own training in the teaching of the science process skills.

Clackamas High School

The teacher estimates of the percentage of total instructional time devoted to the science process skills identified in the district minimum graduation competencies were 20 percent and 60 percent in the area of physical science and 35 percent and 95 percent in the area of biology. All teachers indicated no change over prior years in either the amount of time or emphasis devoted to the science process skills.

Two teachers, one biology and one physical science, indicated having completed one or more classes more than five years ago that were devoted in their entirety or had a major component devoted to the science process skills.

Milwaukie High School

The teacher estimates of the percentage of total instructional time devoted to the science process skills identified in the district's minimum graduation competencies were 20 percent (biology), 30 percent (biology), 20 percent (earth and space science), and 100 percent (integrated science). All teachers indicated no changes over prior years in the amount of time or emphasis devoted to the science process skills. One teacher responded even though it was the first year of teaching for that person.

The Milwaukie High School teachers indicated that none of them had experienced any inservice activities, classes, or workshops that were devoted entirely or had a major component devoted to the science process skills.

Rex Putnam High School

The teacher estimates of the percentage of total unified science instructional time devoted to the science process skills identified in the district's minimum graduation competencies were 75 percent, 80 percent, 80 percent, and 95 percent. One teacher was teaching unified science for the first time and therefore did not respond to the item asking about changes in emphasis or time devoted to the science process skills. One teacher indicated that he had increased both time and emphasis devoted to the science process skills during the 1981-82 school year, while the two remaining teachers indicated no changes over prior years.

One teacher, the first-year instructor, reported no inservice, classes, or workshops concerned with the science process skills. However, since there is no Teacher Guide for the Rex Putnam Unified Science course, any questions about the materials needed to be answered by one or more of the teacher/developers in the building.

Consequently, a certain degree of building level inservice training transpired during this teacher's implementation of the materials throughout the year.

Another teacher, who was involved only in the final stages of the Unified Science Curriculum Development Project, reported building level inservice during his final year of junior high school science teaching. The other two Rex Putnam teachers both reported their unified science curriculum development work during the prior five years as inservice activity, and both had also completed classes (Portland Project implementation courses) more than five years earlier.

Summary

The mean of teacher estimates of the total percentage of instructional time devoted to the district's minimum competency process skills was 59.17 percent. The mode was 20 percent, and the median was 67.50 percent.

The unified science mean (Rex Putnam High School only) was 82.50 percent. The biology mean was 45.00 percent, and the physical science mean was 40.00 percent. The single earth and space science estimate was 20 percent, and the single integrated science estimate was 100 percent.

The three overall school means were 52.50 percent (Clackamas), 42.50 percent (Milwaukie), and 82.50 percent (Rex Putnam).

The emphases on the science process skills declared by the first-level science teachers showed a general relationship to the SPCT posttest scores, SPCT pretest/posttest gains, SPCT Subtest gains, and effect sizes. The groups whose teachers had indicated the greatest emphasis on the science process skills had the highest SPCT posttest scores, greatest SPCT pretest/posttest gains, largest number of SPCT Subtests where statistically significant gains were made, and largest effect sizes. The only exception to that pattern was the Milwaukie ninth-grade Integrated Science group, whose teacher had reported the highest estimate of time devoted to the science process skills; the group had the lowest level of performance in each category discussed above.

No high school level district inservice training in the science process skills was reported, and the only building level inservice activity reported was the Unified Science Curriculum Development Project at Rex Putnam High School. One-third of the teachers reported completing classes concerned with the science process skills more than five years earlier.

Summary Discussion of Sample One Findings

The most consistent and frequent finding from the analysis of the Sample One data was the very strong relationship that existed between academic achievement and science process skill competency as measured by the SPCT. This is especially true for achievement in the areas of mathematics and reading. SPCT posttest variance had greater percentages accounted for by academic achievement than by any other variable.

Academic achievement

In all six regression analyses of Sample One data, mathematics achievement was significant ($p < .001$) and the most important predictor variable, accounting for an average of 38.52 percent of the variance. Reading achievement was also a significant ($p < .001$) predictor variable in two regression equations, and language achievement was a significant ($p < .001$) variable in one regression equation.

SPCT pretest

The mean SPCT pretest score for Sample One students was 9.59 (out of a possible 24 points). SPCT pretest score was the second most important variable in accounting for SPCT posttest variance of Sample One students; it was a significant ($p < .001$) predictor variable in all initial regression equations and accounted for an average of 7.91 percent of the variance.

Type of science

The t-tests of SPCT pretest/posttest gains indicated that all types of science were showing gains at about the same statistical level of significance ($p \leq .05$). The t-tests of the changes on SPCT Subtests detected some differences. While several of the types of science had significant ($p \leq .05$) gains on four or five of the Subtests, only the Rex Putnam Unified Science course had students make significant gains on all six Subtests. These gains were made by both ninth- and tenth-grade students. The Milwaukie ninth-grade

Integrated Science group had the smallest number of significant gains on the Subtests, with only one.

The effect sizes or Δ values for each of the groups in Sample One identified some additional differences. The Clackamas Physical Science groups had the two highest effect sizes (0.82 and 0.90) in the study, followed by the two Rex Putnam High School Unified Science groups (0.68 and 0.74). Both of these types of science, physical science and unified science, had distinctly larger effect sizes than the other groups and types of science in the study. The only other effect size that would be considered above average when compared to those reported in the literature would be the 0.51 of the Clackamas tenth-grade Biology group.

The ANCOVA results indicated significant ($p < .001$) school differences. The students at Clackamas and Rex Putnam High Schools had significantly higher adjusted SPCT posttest scores than the students at Milwaukie High School. This indicates that the Unified Science course at Rex Putnam and Physical Science and Biology courses at Clackamas are producing students with higher levels of science process skill knowledge than are the three first-level courses at Milwaukie. The three courese, Biology, Earth and Space Science, and Integrated Science, at Milwaukie show great similarity in terms of significant pretest/posttest gains, effect sizes, and significant Subtest gains.

There is no "best" type of science emerging from the analysis of the data. Differences do exist, however, as have just been discussed.

There is an element of science process skill development not yet discussed; this is the science process skill competency of students who have left the first-level science course, but who are still in the high schools. Sample Two data analysis reported later in this chapter provides information relative to this dimension of the first-level science courses.

Grade level

In all comparisons, the data consistently indicated higher scores for students who had studied their first-level science in the tenth grade when compared to students who had studied it in the ninth grade. For the total Sample One data, tenth-grade students had significantly ($p < .001$) higher adjusted SPCT scores than did ninth-grade students. The only exception to this general finding was for selected groups of ninth-grade students who had high levels of achievement in the areas of mathematics, reading, and language.

Sex

Sex was found to be a significant ($p < .001$) variable in accounting for SPCT posttest variance in three of six regression equations. In all cases, males had significantly higher scores than females, and the average amount of variance accounted for by the sex variable was 1.85 percent.

Age

Age was not found to account for two percent or more of the SPCT posttest variance in any of the initial regression analyses of Sample One data.

Sample Two

Descriptive Statistics

CAT scores

Table 44 presents mean CAT scores for total reading, total language, and total mathematics for each group in Sample Two. The highest group mean, 56.53 in mathematics, and the lowest group mean, 49.37 in language, both belonged to the Rex Putnam 12th-grade group. The means for all students were 53.53 in reading, 51.87 in language, and 53.87 in mathematics. The ranges of the CAT means were 3.40 for reading, 5.13 for language, and 4.50 for mathematics.

Five of the seven groups had their lowest mean in language. Both Clackamas groups had their highest means in reading, while both Rex Putnam groups had their highest means in mathematics. The group with the highest total CAT means was the Clackamas 12th-grade (162.87), while the group with the lowest total CAT means was the Milwaukie 11th-grade group (155.59).

The average total CAT means for schools were 162.81 for Clackamas, 157.92 for Milwaukie, and 157.41 for Rex Putnam.

The average total CAT means for each grade level were 160.61 for the 10th grade, 158.14 for the 11th grade, and 159.72 for the 12th grade. The only apparent pattern in the CAT means across grade levels was an inverse relationship between language means and grade level.

SPCT

Table 44 presents the mean SPCT scores for each group in Sample Two. The highest mean score was 13.77 (Rex Putnam 12th grade), the lowest mean score 10.70 (Milwaukie 11th grade), and the mean score for all students 12.11. The range for the SPCT group means was 3.07.

The mean SPCT scores for each school were 12.44 for Clackamas, 11.19 for Milwaukie, and 13.17 for Rex Putnam. With one exception, the Milwaukie 11th-grade group, SPCT scores increased with grade level within each school.

The mean SPCT scores for each grade level were 11.40 for the 10th grade, 11.85 for the 11th grade, and 12.61 for the 12th grade.

SPCT Subtests

Table 44 presents the mean SPCT Subtest scores for each group in Sample Two. The SPCT contains six Subtests, one for each of the process skill competency areas included in the study. Scores on each Subtest can range from zero to four. The highest group mean on any Subtest was 2.87 (Interpreting Data); the lowest group mean on any Subtest was 0.63 (Modeling).

The total Sample Two means for the SPCT Subtests were 2.33 (Classifying), 2.19 (Observing), 2.61 (Interpreting Data), 1.92 (Identifying Variables), 0.92 (Modeling), and 2.04 (Measuring). The grand Sample Two mean for all Subtests was 2.02.

Summary

The highest overall CAT achievement area for Sample Two students was mathematics, followed closely by reading. The individual group with the highest total CAT means was the Clackamas 12th-grade group, and the group with the lowest total CAT means was the Milwaukie 11th-grade group. Clackamas High School students had a total CAT mean score (162.81) that was 4.89 higher than that of Milwaukie High School students and 5.40 higher than that of Rex Putnam High School students. The total CAT mean scores for the three grade levels included in Sample Two were very similar, with a range of 2.47 and grand mean of 159.49.

The SPCT mean for all students in Sample Two was 12.11. The highest SPCT mean for an individual group was 13.77 for the Rex Putnam 12th-grade group. The lowest SPCT mean for an individual group was 10.70 for the Milwaukie 11th-grade group. Sample Two student SPCT means increased with grade level, with a 0.45 increase between grades 10 and 11 and a 0.76 increase between grades 11 and 12. Rex Putnam High School students had the highest school mean, 13.17, and Milwaukie High School students the lowest school mean, 11.19.

The SPCT Subtest with the highest total student mean was Interpreting Data (2.61). The Subtest with the lowest total student mean was Modeling (0.92). Five of the seven group means on the Modeling Subtest were near the probability level for guessing.

Total student means were almost identical for the Classifying (2.33) and Observing (2.29) Subtests, which represented the second and third highest total student means for any Subtests. Milwaukie High School students had the lowest mean on each Subtest, and the 12th-grade students had the highest grade-level mean on each Subtest.

TABLE 44

SAMPLE TWO MEANS OF SPCT SCORES AND CAT SCORES BY SCHOOL AND GRADE LEVEL

Group	N	SPCT	Classify	Observe	Interpret	Variable	Model	Measure	CAT Read	CAT Lang	CAT Math
Clackamas 11	30	12.27	2.37	2.30	2.87	2.03	0.63	2.07	55.47	54.50	52.77
Clackamas 12	30	12.60	2.57	2.50	2.60	1.77	0.87	2.30	55.17	53.00	54.70
Milwaukie 10	30	11.40	2.27	2.27	2.60	1.90	0.70	1.67	53.17	53.27	54.17
Milwaukie 11	30	10.70	2.07	2.17	2.20	1.40	0.80	2.07	51.93	51.23	52.43
Milwaukie 12	30	11.47	2.13	2.13	2.57	2.00	0.70	1.93	54.37	51.17	52.03
Rex Putnam 11	30	12.57	2.30	2.27	2.60	2.17	1.33	1.90	51.77	50.53	53.80
Rex Putnam 12	30	13.77	2.63	2.40	2.83	2.17	1.40	2.33	52.83	49.37	56.53

Regression Analysis of Total Sample Two SPCT Variance

Table 45 presents the results of multiple regression analysis of all Sample Two student SPCT scores. There were 35 independent variables entered into the multiple regression procedure. For all multiple regression analyses in this study, the equation selected for presentation and discussion was the one that contained all predictor variables that accounted for approximately two percent or more of the variance.

The main regression equation contained five predictor variables that collectively accounted for 54.95 percent of the variance and had an F-value of 49.51 with 5 and 203 degrees of freedom. This was significant at $p < .001$. The most important predictor variable was mathematics achievement, which accounted for 41.70 percent of the variance. The other predictor variables in the equation, in decreasing order of importance, were reading achievement, Unified Science, elective science, and sex.

The entry of unified science into the equation was significant for two reasons. First, it was the only instance where a first-level type of science appeared in a total sample regression equation. In addition, it accounted for a larger share of the variance (3.22 percent) than did having completed some elective science (1.59 percent).

Removal of the strongest predictor, mathematics achievement, from the list of independent variables and repetition of the multiple regression procedure produced the results found in table 46.

This regression equation contained six predictor variables that collectively accounted for 53.55 percent of the variance. The equation F-value was 38.81 with 6 and 202 degrees of freedom, which was significant at $p < .001$.

The most important predictor variable in this second equation was reading achievement, which accounted for 38.86 percent of the variance. The other variables in the equation, in decreasing order of importance, were unified science, mathematics beyond algebra, one semester of physics, language achievement, and sex.

Of special interest in equation two are the disappearance of elective science and the entry of mathematics beyond algebra, language achievement, and one semester of physics. The disappearance of elective science was due primarily to its strong positive relationship to mathematics beyond algebra, which entered the equation on step three. Mathematics beyond algebra had a strong positive relationship to mathematics achievement, and therefore when mathematics achievement was removed from the list of independent variables, mathematics beyond algebra emerged as a reasonably important predictor. The entry of language achievement into the equation indicates that it is somewhat independent of reading achievement and accounts for a portion of the SPCT variance for other reasons; most likely this is a reflection of its positive relationship to mathematics achievement. The entry of one semester of physics was indicative of its strong positive relationship to mathematics achievement and relative independence from the variables preceding it in the equation.

TABLE 45

Total Sample Two Multiple Regression of 35 Variables on SPCT Posttest Scores

```
                      MULTIPLE R              0.74125
                      R SQUARE                0.54945
                      ADJUSTED R SQUARE       0.53836
                      STANDARD ERROR          2.65509


ANALYSIS OF VARIANCE      DF     SUM OF SQUARES    MEAN SQUARE        F
REGRESSION                 5.       1745.20230      349.04046    49.51287
RESIDUAL                 203.       1431.04650        7.04949


    ------------------- VARIABLES IN THE EQUATION -------------------

    VARIABLE           B             BETA      STD ERROR B          F

    CATMATH     0.1407143          0.33378       0.02728        26.607
    CATREAD     0.1805350          0.39037       0.02974        36.842
    TYPESC4      1.525959          0.17795       0.41650        13.295
    ELECSCI     0.9699896          0.12303       0.41761         5.390
    SEX         0.8584954          0.11011       0.37286         5.301
    (CONSTANT)  -0.411062

      ----------------- VARIABLES NOT IN THE EQUATION -----------------

      VARIABLE        BETA IN       PARTIAL    TOLERANCE            F

      CATLANG         0.11355       0.10084      0.37530        2.075
      AGE             0.01582       0.02290      0.94374        0.106
      GRADE10        -0.01141      -0.01642      0.93430        0.055
      GRADE11        -0.01726      -0.02558      0.98958        0.132
      GRADE12         0.02565       0.03748      0.96205        0.284
      CLACKHI         0.07973       0.10766      0.82151        2.369
      MILHI          -0.08449      -0.10846      0.74253        2.405
      PUTHI           0.03617       0.01598      0.08798        0.052
      YRREM1          0.03753       0.05310      0.90177        0.571
      YRREM2         -0.01206      -0.01771      0.97165        0.063
      YRREM3         -0.03808      -0.05437      0.91670        0.599
      TYPESC1         0.03631       0.04378      0.65491        0.388
      TYPESC2        -0.05965      -0.08652      0.94801        1.524
      TYPESC3         0.01107       0.01503      0.83338        0.046
      SMELSC1        -0.06788      -0.09856      0.94976        1.981
      SMELSC2        -0.01547      -0.01691      0.53302        0.058
      SMELSC3         0.02935       0.04288      0.92102        0.369
      SMELSC4        -0.03860      -0.05336      0.86098        0.577
      SMELSC5         0.02162       0.03064      0.90507        0.193
      SMELSC6         0.05965       0.08484      0.91144        1.464
      SMELSC7         0.01885       0.02777      0.97749        0.156
      SMELSC8        -0.00495      -0.00729      0.97566        0.011
      BIO1           -0.04225      -0.05404      0.73703        0.592
      BIO2           -0.03841      -0.04937      0.74430        0.494
      CHEM1           0.05971       0.05673      0.40670        0.652
      CHEM2           0.07903       0.07618      0.41640        1.179
      PHY1            0.06987       0.08797      0.71432        1.575
      PHY2            0.07197       0.09550      0.79331        1.859
      ADVCHEM1        0.07409       0.10345      0.87329        2.185
      BYNDALG         0.07839       0.08144      0.48827        1.349
                              SUMMARY TABLE

        VARIABLE      MULTIPLE R   R SQUARE   RSQ CHANGE    SIMPLE R

        CATMATH         0.64577    0.41701      0.41701     0.64577
        CATREAD         0.69973    0.48962      0.07261     0.62337
        TYPESC4         0.72237    0.52182      0.03220     0.17232
        ELECSCI         0.73327    0.53769      0.01587     0.42960
        SEX             0.74125    0.54945      0.01177     0.06399
```

TABLE 46

Total Sample Two Multiple Regression of 34 Variables on SPCT Posttest Scores with Mathematics Achievement Removed

```
                    MULTIPLE R              0.73179
                    R SQUARE                0.53551
                    ADJUSTED R SQUARE       0.52172
                    STANDARD ERROR          2.70252

ANALYSIS OF VARIANCE      DF     SUM OF SQUARES    MEAN SQUARE        F
REGRESSION                6.        1700.92119      283.48686    38.81466
RESIDUAL                202.        1475.32762        7.30360


   ------------------- VARIABLES IN THE EQUATION --------------------

   VARIABLE             B            BETA     STD ERROR B         F

   CATREAD     0.1540891          0.33319        0.03682     15.757
   TYPESC4      1.677095          0.19558        0.43825     14.644
   BYNDALG      1.561942          0.19750        0.47610     10.763
   PHY1         2.007140          0.16113        0.66759      9.039
   CATLANG     0.1019696          0.21503        0.03751      7.392
   SEX         0.9324400          0.11959        0.38254      5.942
   (CONSTANT)  -3.514214

     ------------ VARIABLES NOT IN THE EQUATION ---------------

     VARIABLE       BETA IN       PARTIAL    TOLERANCE           F

     AGE            0.01715       0.02355      0.87369       0.112
     ELECSCI        0.09022       0.11096      0.70254       2.506
     GRADE10       -0.02722      -0.03869      0.95504       0.301
     GRADE11       -0.00243      -0.00346      0.94198       0.002
     GRADE12        0.02278       0.03179      0.90479       0.203
     CLACKMI        0.05374       0.07138      0.81900       1.029
     MILMI         -0.06319      -0.07963      0.73602       1.263
     PUTMI          0.08238       0.03533      0.85541       0.251
     YRREM1         0.02088       0.02970      0.93956       0.177
     YRREM2         0.01639       0.02396      0.99252       0.115
     YRREM3        -0.05678      -0.07834      0.88450       1.241
     TYPESC1        0.04484       0.05387      0.67035       0.585
     TYPESC2       -0.06264      -0.08906      0.93300       1.607
     TYPESC3        0.00341       0.00464      0.85953       0.004
     SMELSC1       -0.05718      -0.08288      0.97088       1.383
     SMELSC2        0.07199       0.10188      0.92855       2.100
     SMELSC3        0.06296       0.08900      0.92619       1.605
     SMELSC4       -0.03225      -0.04568      0.93180       0.420
     SMELSC5        0.00300       0.00390      0.78372       0.003
     SMELSC6        0.05221       0.07065      0.85048       1.008
     SMELSC7        0.01885       0.02732      0.97559       0.150
     SMELSC8       -0.01991      -0.02798      0.91727       0.157
     BIO1          -0.02053      -0.02854      0.89737       0.164
     BIO2          -0.01374      -0.01927      0.91443       0.075
     CHEM1          0.09441       0.11433      0.68110       2.662
     CHEM2          0.11101       0.13634      0.70069       3.807
     PHY2           0.02575       0.01639      0.18314       0.054
     ADVCHEM1       0.09494       0.12695      0.85700       3.399

                              SUMMARY TABLE

     VARIABLE          MULTIPLE R   R SQUARE   RSQ CHANGE    SIMPLE R

     CATREAD              0.62337    0.38859      0.38859     0.62337
     TYPESC4              0.66778    0.44593      0.05733     0.17232
     BYNDALG              0.70006    0.49009      0.04416     0.54442
     PHY1                 0.71326    0.50874      0.01866     0.38403
     CATLANG              0.72239    0.52185      0.01311     0.54437
     SEX                  0.73179    0.53551      0.01366     0.06399
```

Regression Analysis of SPCT Posttest Variance by Grade Level

Tenth grade

Table 47 presents the results of the multiple regression analysis of Sample Two tenth-grade SPCT scores. The regression equation contained three predictor variables that collectively accounted for 50.19 percent of the variance. The F-value for the equation was 8.73 with 3 and 26 degrees of freedom, which was significant at $p < .001$.

The most important predictor variable was mathematics achievement, which accounted for 41.78 percent of the variance. The other predictor variables, in decreasing order of importance, were unified science and mathematics beyond algebra. It should be kept in mind that tenth-grade students in Sample Two were all from Milwaukie High School.

Removal of the most important predictor variable, mathematics achievement, from the list of independent variables and repetition of the multiple regression analysis produced the results found in table 48. The second regression equation contained two predictor variables that collectively accounted for 38.24 percent of the variance. The F-value for the equation was 8.36 with 2 and 27 degrees of freedom, which was significant at $p < .005$.

The most important predictor variable was mathematics beyond algebra, which accounted for 34.98 percent of the variance. The other predictor variable in the equation was earth and space science, which had a negative regression coefficient and accounted for 3.25 percent of the variance.

TABLE 47

Sample Two Tenth-Grade Multiple Regression
of 13 Variables on SPCI Scores

```
                    MULTIPLE R            0.70845
                    R SQUARE              0.50190
                    ADJUSTED R SQUARE     0.44443
                    STANDARD ERROR        2.69528


ANALYSIS OF VARIANCE      DF    SUM OF SQUARES    MEAN SQUARE        F
REGRESSION                 3.        190.32166       63.44055    8.73289
RESIDUAL                  26.        188.87834        7.26455


   ---------------- VARIABLES IN THE EQUATION ----------------

   VARIABLE          B            BETA     STD ERROR B        F

   CATMATH     0.1981383        0.52381       0.07628       6.748
   TYPESC4      2.749136        0.23196       1.71375       2.573
   BYNDALG      1.964760        0.26631       1.45563       1.822
   (CONSTANT) -0.8517552


    ------------ VARIABLES NOT IN THE EQUATION ------------

    VARIABLE       BETA IN      PARTIAL    TOLERANCE          F

    CATREAD       -0.11418     -0.10446      0.41691      0.276
    CATLANG       -0.22353     -0.18575      0.54593      0.893
    SEX            0.12692      0.15567      0.75120      0.622
    AGE           -0.12906     -0.16049      0.76991      0.661
    ELECSCI       -0.03282     -0.04106      0.77964      0.042
    TYPESC1        0.02489      0.03034      0.74024      0.023
    TYPESC2       -0.02404     -0.03034      0.79337      0.023
    SMELSC2       -0.03282     -0.04106      0.77964      0.042
    CHEM1         -0.03282     -0.04106      0.77964      0.042
    CHEM2         -0.03282     -0.04106      0.77964      0.042


                           SUMMARY TABLE

    VARIABLE        MULTIPLE R   R SQUARE   RSQ CHANGE    SIMPLE R

    CATMATH            0.64640    0.41784      0.41784     0.64640
    TYPESC4            0.68337    0.46700      0.04916     0.02500
    BYNDALG            0.70845    0.50190      0.03490     0.59146
```

TABLE 48

Sample Two Tenth-Grade Multiple Regression of 12 Variables on SPCT Scores with Mathematics Achievement Removed

```
                        MULTIPLE R           0.61836
                        R SQUARE             0.38237
                        ADJUSTED R SQUARE    0.33662
                        STANDARD ERROR       2.94522

                                                                           F
ANALYSIS OF VARIANCE        DF     SUM OF SQUARES    MEAN SQUARE      8.35763
REGRESSION                   2.         144.99342       72.49671
RESIDUAL                    27.         234.20658        8.67432


     ---------------- VARIABLES IN THE EQUATION ----------------

     VARIABLE              B           BETA     STD ERROR B          F

     BYNDALG        4.177171        0.56619        1.12675      13.744
     TYPESC2       -1.343838       -0.18215        1.12675       1.422
     (CONSTANT)     9.247199


       ------------ VARIABLES NOT IN THE EQUATION -------------

       VARIABLE        BETA IN      PARTIAL    TOLERANCE          F

       CATREAD         0.04447      0.04145      0.53671      0.045
       CATLANG         0.12882      0.12483      0.58002      0.412
       SEX             0.04213      0.05292      0.97464      0.073
       AGE            -0.13225     -0.14521      0.74461      0.560
       ELECSCI         0.08410      0.09612      0.80680      0.242
       TYPESC1        -0.18289     -0.13094      0.31663      0.454
       TYPESC4         0.10998      0.13094      0.87561      0.454
       SMELSC2         0.08410      0.09612      0.80680      0.242
       CHEM1           0.08410      0.09612      0.80680      0.242
       CHEM2           0.08410      0.09612      0.80680      0.242


                             SUMMARY TABLE

       VARIABLE        MULTIPLE R   R SQUARE   RSQ CHANGE    SIMPLE R

       BYNDALG           0.59146     0.34983     0.34983      0.59146
       TYPESC2           0.61836     0.38237     0.03254     -0.26071
```

11th grade

Table 49 presents the results of the multiple regression analysis of Sample Two 11th-grade student SPCT scores. The regression equation contained four predictor variables that collectively accounted for 52.85 percent of the variance. The F-value was 23.54 with 4 and 84 degrees of freedom, which was significant at $p < .001$.

The most important predictor variable was reading achievement, which accounted for 42.60 percent of the variance. The other predictor variables, in decreasing order of importance, were elective science, earth and space science, and physics. Earth and space science had a negative regression coefficient.

Removal of the most important predictor variable, reading achievement, from the list of independent variables and repetition of the multiple regression analysis produced the results found in table 50. The new regression equation contained seven predictor variables, and they collectively accounted for 56.74 percent of the variance. The F-value for the equation was 15.18 with 7 and 81 degrees of freedom, which was significant at $p < .001$.

The most important predictor variable was mathematics achievement, accounting for 36.23 percent of the variance. The other predictor variables in the equation, in decreasing order of importance, were language achievement, physics, chemistry, Milwaukie High School, sex, and earth and space science. Milwaukie High School and earth and space science both had negative regression coefficients.

The examination of the simple correlation coefficients and the results of the two regression analyses emphasize the importance of academic schievement in reading, mathematics, and language as predictor variables. Also of interest is the disappearance of elective science from the second equation. Most of the importance of elective science as a predictor was included in the chemistry and physics variables, which entered the equation in steps three and four. Earth and Space Science, a first-level science course, was a predictor variable with a negative correlation coefficient in both equations. The sex variable in the second equation was a reflection of males having significantly higher scores than females.

TABLE 49

Sample Two 11th-Grade Multiple Regression of 25 Variables on SPCT Scores

```
                         MULTIPLE R            0.72698
                         R SQUARE              0.52849
                         ADJUSTED R SQUARE     0.50604
                         STANDARD ERROR        2.76101


ANALYSIS OF VARIANCE      DF      SUM OF SQUARES    MEAN SQUARE       F
REGRESSION                 4.        717.74106       179.43526     23.5380
RESIDUAL                  84.        640.34883         7.62320

   --------------- VARIABLES IN THE EQUATION ---------------

   VARIABLE           B            BETA       STD ERROR B        F

   CATREAD     0.2548654         0.55570       0.03632       49.253
   ELECSCI      1.487336         0.18599       0.64357        5.341
   TYPESC2     -6.408258        -0.17291       2.79354        5.262
   PHY2         3.536290         0.16338       1.67277        4.469
   (CONSTANT)  -2.315553

    ------------- VARIABLES NOT IN THE EQUATION --------------

    VARIABLE       BETA IN      PARTIAL    TOLERANCE          F

    CATLANG        0.20817      0.17535      0.33458        2.63
    CATMATH        0.17428      0.17380      0.46395        2.58
    SEX            0.08817      0.12292      0.91628        1.27
    AGE            0.09874      0.13461      0.37644        1.53
    CLACKHI       -0.01953     -0.02745      0.93173        0.06
    MILHI         -0.09624     -0.13635      0.95332        1.58
    PUTHI          0.12320      0.17022      0.90007        2.47
    TYPESC1       -0.09292     -0.12919      0.91146        1.40
    TYPESC3       -0.01575     -0.02222      0.93551        0.04
    TYPESC4        0.11735      0.16089      0.88631        2.20
    SMELSC1       -0.09219     -0.12717      0.89720        1.36
    SMELSC2        0.07689      0.07441      0.44164        0.46
    SMELSC3        0.11974      0.17225      0.97576        2.53
    SMELSC4       -0.08586     -0.11744      0.98222        1.16
    SMELSC6        0.01830      0.02173      0.66478        0.03
    BIO1          -0.13773     -0.16365      0.66573        2.28
    BIO2          -0.15622     -0.18459      0.65828        2.92
    CHEM1          0.06462      0.05741      0.51302        0.37
    CHEM2          0.08094      0.08546      0.53793        0.62
    PHY1           0.08981      0.08244      0.39731        0.56
    BYNDALG        0.08601      0.09384      0.56132        0.73

                             SUMMARY TABLE

    VARIABLE         MULTIPLE R  R SQUARE  RSQ CHANGE   SIMPLE R

    CATREAD            0.65266    0.42597    0.42597     0.65266
    ELECSCI            0.68860    0.47417    0.04821     0.40948
    TYPESC2            0.70951    0.50341    0.02923    -0.24284
    PHY2               0.72698    0.52849    0.02509     0.29171
```

TABLE 50

Sample Two 11th-Grade Multiple Regression of 24 Variables on SPCT Scores with Reading Achievement Removed

```
                    MULTIPLE R              0.75326
                    R SQUARE                0.56740
                    ADJUSTED R SQUARE       0.53002
                    STANDARD ERROR          2.65318


ANALYSIS OF VARIANCE      DF     SUM OF SQUARES   MEAN SQUARE        F
REGRESSION                 7.         770.58120     110.08303   15.17718
RESIDUAL                  81.         587.50869       7.25319


    -------------- VARIABLES IN THE EQUATION ----------------

    VARIABLE          B            BETA      STD ERROR B         F

    CATMATH     0.8421941D-01    0.19672       0.04593         3.363
    CATLANG     0.1995159        0.41390       0.04901        16.57
    PHY2         3.589896        0.16566       1.69302         4.496
    CHEM2        1.721517        0.18395       0.75268         5.231
    MILHI       -1.335398       -0.16160       0.62771         4.526
    SEX          1.223163        0.15608       0.59843         4.178
    TYPESC2     -5.430617       -0.14653       2.77625         3.826
    (CONSTANT)  -3.573545


      ------------ VARIABLES NOT IN THE EQUATION -------------

      VARIABLE       BETA IN      PARTIAL    TOLERANCE         F

      AGE            0.12089      0.16843     0.83980        2.336
      ELECSCI       -0.00842     -0.00883     0.47614        0.006
      CLACKMI       -0.08722     -0.10698     0.65076        0.926
      PUTHI          0.08648      0.10698     0.66198        0.926
      TYPESC1       -0.02485     -0.03282     0.75495        0.086
      TYPESC3       -0.02290     -0.03275     0.86430        0.086
      TYPESC4        0.05733      0.07149     0.67265        0.411
      SMELSC1       -0.07454     -0.11029     0.94695        0.985
      SMELSC2        0.04984      0.06811     0.80771        0.373
      SMELSC3        0.11172      0.16410     0.93528        2.214
      SMELSC4       -0.08692     -0.11403     0.74463        1.054
      SMELSC6       -0.04416     -0.05065     0.56919        0.206
      BIO1          -0.14266     -0.19036     0.77024        3.008
      BIO2          -0.13796     -0.18738     0.79798        2.911
      CHEM1         -0.17564     -0.06511     0.05944        0.341
      PHY1           0.07583      0.07065     0.37552        0.401
      BYNDALG        0.01491      0.01543     0.46289        0.019

                           SUMMARY TABLE

      VARIABLE       MULTIPLE R  R SQUARE  RSQ CHANGE   SIMPLE R

      CATMATH         0.60191    0.36230    0.36230     0.60191
      CATLANG         0.65409    0.42783    0.06553     0.59194
      PHY2            0.68636    0.47109    0.04325     0.29171
      CHEM2           0.70923    0.50297    0.03188     0.38606
      MILHI           0.72682    0.52827    0.02530    -0.21885
      SEX             0.73957    0.54697    0.01870     0.08740
      TYPESC2         0.75326    0.56740    0.02044    -0.24284
```

12th grade

Table 51 presents the results of the multiple regression analysis of Sample Two 12th-grade student SPCT scores. The regression equation contained three predictor variables that collectively accounted for 59.36 percent of the variance. The F-value was 41.87 with 3 and 86 degrees of freedom, which was significant at $p < .001$.

The most important predictor variable was mathematics achievement, which accounted for 47.91 percent of the variance. The other predictor variables were reading achievement and Rex Putnam High School, which accounted for 8.40 and 3.05 percent of the variance, respectively.

Removal of the most important predictor variable, mathematics achievement, and repetition of the multiple regression analysis produced the results found in table 52. The new regression equation contained four predictor variables that collectively accounted for 56.92 percent of the variance. The F-value for the equation was 28.08 with 4 and 85 degrees of freedom, which was significant at $p < .001$.

The most important predictor variable was reading achievement, which accounted for 40.90 percent of the variance. The other predictor variables in the equation, in decreasing order of importance, were Rex Putnam High School, mathematics beyond algebra, and one semester of physics.

Summary

The use of multiple regression analysis on the total SPCT scores of Sample Two students revealed a strong relationship between academic achievement and SPCT scores. This relationship was especially strong in the areas of mathematics and reading. Unified science was the only type of first-level science that was found to contribute significantly to accounting for SPTC variance. Sex, favoring males, was a contributing predictor variable. Elective science and one semester of physics were other variables entering into at least one of the two total Sample Two equations.

Analysis of each grade levels' SPCT scores by means of regression analysis produced similar findings to the analysis of the sample as a whole. In grades 10 and 12, mathematics achievement was the most important predictor. In grade 11, reading achievement accounted for the highest percentage of the variance. Unified science was a positive contributor to the variance in the 10th grade, while earth and space science was a negative contributor to the variance in the 11th grade. Elective science was a predictor variable only at the 11th-grade level. The only elective science course to appear in more than one regression was physics, which was present at both the 11th and 12th grade levels.

TABLE 51

Sample Two 12th-Grade Multiple Regression of 27 Variables on SPCT Scores

```
                        MULTIPLE R            0.77044
                        R SQUARE              0.59358
                        ADJUSTED R SQUARE     0.57940
                        STANDARD ERROR        2.56978


ANALYSIS OF VARIANCE        DF     SUM OF SQUARES    MEAN SQUARE           F
REGRESSION                  3.          829.46297      276.48766     41.86803
RESIDUAL                   86.          567.92592        6.60379


     --------------- VARIABLES IN THE EQUATION ---------------

     VARIABLE              B           BETA     STD ERROR B          F

     CATMATH      0.1793543         0.42200         0.03744     22.944
     CATREAD      0.1367762         0.41219         0.03962     22.225
     PUTHI         1.526479         0.18262         0.60103      6.450
     (CONSTANT)   -7.767317


       ------------- VARIABLES NOT IN THE EQUATION -------------

       VARIABLE        BETA IN       PARTIAL    TOLERANCE           F

       CATLANG         0.12934       0.12672      0.39010       1.387
       SEX             0.07848       0.12130      0.97089       1.265
       AGE            -0.00583      -0.00876      0.91900       0.007
       ELECSCI         0.13191       0.18161      0.77044       2.895
       CLACKHI         0.06148       0.08284      0.73791       0.587
       MILHI          -0.06148      -0.08284      0.73791       0.587
       TYPESC1        -0.00967      -0.01277      0.73860       0.014
       TYPESC2        -0.01162      -0.01793      0.96691       0.027
       TYPESC3         0.01642       0.02351      0.83239       0.047
       SMELSC2         0.07996       0.12094      0.92971       1.262
       SMELSC3         0.00362       0.00535      0.88780       0.002
       SMELSC4        -0.02566      -0.03937      0.95670       0.132
       SMELSC5         0.03596       0.05175      0.84181       0.228
       SMELSC6         0.07700       0.11449      0.89844       1.125
       SMELSC7         0.05373       0.08347      0.98084       0.596
       SMELSC8        -0.01622      -0.02490      0.95772       0.053
       BIO1            0.03721       0.05415      0.66079       0.250
       BIO2            0.03721       0.05415      0.86079       0.250
       CHEM1           0.10592       0.13726      0.68255       1.632
       CHEM2           0.10592       0.13726      0.68255       1.632
       PHY1            0.08244       0.10571      0.66826       0.961
       PHY2            0.08331       0.11429      0.76483       1.125
       ADVCHEM1        0.12817       0.17963      0.79837       2.834
       BYNDALG         0.09868       0.10718      0.47942       0.988

                              SUMMARY TABLE

       VARIABLE          MULTIPLE R   R SQUARE   RSQ CHANGE    SIMPLE R

       CATMATH              0.69217    0.47910      0.47910     0.69217
       CATREAD              0.75040    0.56310      0.08399     0.63955
       PUTHI                0.77044    0.59358      0.03048     0.20737
```

TABLE 52

Sample Two 12th-Grade Multiple Regression of 26 Variables on SPCT Scores with Mathematics Achievement Removed

```
                    MULTIPLE R            0.75448
                    R SQUARE              0.56924
                    ADJUSTED R SQUARE     0.54897
                    STANDARD ERROR        2.46114


ANALYSIS OF VARIANCE    DF    SUM OF SQUARES   MEAN SQUARE       F
REGRESSION               4.       795.44784     198.86196    28.0812
RESIDUAL                85.       601.94105       7.08166


   ------------- VARIABLES IN THE EQUATION ---------------

   VARIABLE          B            BETA      STD ERROR B        F

   CATREAD     0.2177713        0.48059      0.03872       31.631
   PUTHI        1.753592        0.20979      0.62475        7.879
   BYNDALG      2.044791        0.24840      0.70458        8.422
   PHY1         1.663029        0.16882      0.79566        4.369
   (CONSTANT)  -1.410048

      ----------- VARIABLES NOT IN THE EQUATION -----------

      VARIABLE      BETA IN      PARTIAL   TOLERANCE          F

      CATLANG       0.17646      0.16734     0.38738         2.42
      SEX           0.08137      0.12167     0.96614         1.26
      AGE          -0.05669     -0.08232     0.90820         0.57
      ELECSCI       0.10340      0.12789     0.65900         1.39
      CLACKHI       0.09883      0.13015     0.74701         1.44
      MILHI        -0.09883     -0.13015     0.74701         1.44
      TYPESC1       0.04461      0.05695     0.70202         0.27
      TYPESC2      -0.01380     -0.02041     0.94201         0.03
      TYPESC3      -0.03451     -0.04752     0.81668         0.19
      SMELSC2       0.08908      0.13032     0.92188         1.45
      SMELSC3       0.06703      0.09910     0.94140         0.83
      SMELSC4      -0.06712     -0.09775     0.91353         0.81
      SMELSC5      -0.01091     -0.01399     0.70911         0.01
      SMELSC6       0.06443      0.09023     0.84475         0.69
      SMELSC7       0.01416      0.02137     0.98186         0.03
      SMELSC8      -0.01932     -0.02605     0.90822         0.06
      BIO1          0.00054      0.00076     0.84707         0.00
      BIO2          0.00054      0.00076     0.84707         0.00
      CHEM1         0.08488      0.09314     0.57583         0.81
      CHEM2         0.08488      0.09814     0.57583         0.81
      PHY2         -0.04773     -0.02641     0.13190         0.05
      ADVCHEM1      0.13738      0.16711     0.79217         3.04

                            SUMMARY TABLE

      VARIABLE      MULTIPLE R  R SQUARE  RSQ CHANGE   SIMPLE R

      CATREAD         0.63955    0.40902    0.40902    0.63955
      PUTHI           0.69653    0.48515    0.07613    0.20737
      BYNDALG         0.73966    0.54710    0.06195    0.56290
      PHY1            0.75448    0.56924    0.02214    0.46527
```

School Differences in Academic Achievement

The importance of academic achievement, especially in the areas of mathematics and reading, to science process skill knowledge became apparent as a result of the examination of the simple correlation coefficients and the results of multiple regression analysis of the Sample Two data. One-way analysis of variance (ANOVA) was used to identify any school differences in academic achievement that existed in the areas of mathematics, reading, and language.

CAT reading

Table 53 presents the ANOVA results for reading achievement in the three schools. No significant difference was found at $p < .05$.

CAT language

Table 53 presents the ANOVA results for language achievement in the three schools, and table 54 presents the one-way ANOVA results for all possible pairings between the three schools. The initial ANOVA indicated that a significant difference existed at $p = .043$. The school comparison ANOVA's found only one significant difference. Clackamas High School students scored significantly higher ($p = .010$) than did Rex Putnam High School students on the CAT total language measure.

CAT mathematics

Table 53 presents the ANOVA results for mathematics achievement in the three schools. No significant difference was found at $p < .05$.

TABLE 53

Total Sample Two Analysis of Variance of CAT Reading, Language, and Mathematics Achievement Scores by School

READING

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	294.923	2	147.461	2.032	0.134
ID	294.923	2	147.461	2.032	0.134
EXPLAINED	294.926	2	147.463	2.032	0.134
RESIDUAL	15021.066	207	72.566		
TOTAL	15315.992	209	73.282		

LANGUAGE

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	433.278	2	216.639	3.192	0.043
ID	433.276	2	216.639	3.192	0.043
EXPLAINED	433.281	2	216.641	3.192	0.043
RESIDUAL	14048.703	207	67.868		
TOTAL	14481.984	209	69.292		

MATHEMATICS

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	188.759	2	94.379	1.091	0.338
ID	188.759	2	94.379	1.091	0.338
EXPLAINED	188.762	2	94.381	1.091	0.338
RESIDUAL	17901.371	207	86.480		
TOTAL	18090.133	209	86.556		

TABLE 54

Sample Two Analysis of Variance of CAT Language Achievement Scores by School Comparisons

CLACKAMAS VS MILWAUKIE

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	124.694	1	124.694	1.882	0.172
ID	124.694	1	124.694	1.882	0.172
EXPLAINED	124.695	1	124.695	1.882	0.172
RESIDUAL	9805.977	148	66.257		
TOTAL	9930.672	149	66.649		

CLACKAMAS VS PUTNAM

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	433.200	1	433.200	6.900	0.010
ID	433.200	1	433.200	6.900	0.010
EXPLAINED	433.203	1	433.203	6.900	0.010
RESIDUAL	7407.988	118	62.780		
TOTAL	7841.191	119	65.892		

MILWAUKIE VS PUTNAM

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	135.334	1	135.334	1.840	0.177
ID	135.334	1	135.334	1.840	0.177
EXPLAINED	135.336	1	135.336	1.840	0.177
RESIDUAL	10883.539	148	73.537		
TOTAL	11018.875	149	73.952		

Regression Analysis of SPCT Variance by School

Clackamas High School

Table 55 presents the results of the multiple regression analysis of Sample Two Clackamas High School SPCT scores. The regression equation contained three predictor variables that collectively accounted for 44.16 percent of the variance. The F-value for the equation was 14.76 with 3 and 56 degrees of freedom, which was significant at $p < .001$.

The most important predictor variable was reading achievement, accounting for 32.98 percent of the variance. The other predictor variables were two semesters of elective science and mathematics achievement, accounting for 6.67 and 4.52 percent of the variance, respectively.

Removal of the most important predictor variable, reading achievement, from the list of independent variables and repetition of the multiple regression analysis produced the results found in table 56. The new equation contained three predictor variables that collectively accounted for 39.76 percent of the variance. The F-value for the equation was 12.32 with 3 and 56 degrees of freedom, which was significant at $p < .001$.

The most important predictor variable was mathematics achievement, which accounted for 31.16 percent of the variance. The other two variables in the equation were two semesters of elective science and language achievement, accounting for 6.17 and 2.42 percent of the variance, respectively.

TABLE 55

Sample Two Clackamas High School Multiple Regression of 19 Variables on SPCT Scores

```
                    MULTIPLE R             0.66455
                    R SQUARE               0.44163
                    ADJUSTED R SQUARE      0.41171
                    STANDARD ERROR         2.50381


ANALYSIS OF VARIANCE      DF     SUM OF SQUARES    MEAN SQUARE        F
REGRESSION                 3.         277.66494       92.55498    14.76373
RESIDUAL                  56.         351.06839        6.26908


   ---------------- VARIABLES IN THE EQUATION -------------------

   VARIABLE           B            BETA       STD ERROR B        F

   CATREAD      0.1456626        0.34323        0.05568        6.845
   SMELSC2       1.632560        0.23460        0.71748        5.177
   CATMATH      0.1113108        0.26096        0.05229        4.531
   (CONSTANT)   -2.122313


     ------------- VARIABLES NOT IN THE EQUATION -------------

     VARIABLE      BETA IN      PARTIAL    TOLERANCE          F

     CATLANG       0.02069      0.01709      0.38098        0.016
     SEX           0.06632      0.08465      0.90964        0.397
     AGE           0.02619      0.03471      0.98107        0.066
     ELECSCI      -0.03985     -0.03270      0.37580        0.059
     TYPESC1      -0.03135     -0.04191      0.99787        0.097
     TYPESC3       0.03135      0.04191      0.99787        0.097
     SMELSC4      -0.07495     -0.09743      0.94357        0.527
     SMELSC6       0.10609      0.13443      0.89661        1.012
     SMELSC8      -0.08649     -0.11293      0.95202        0.711
     BIO1         -0.03844     -0.04984      0.93852        0.137
     BIO2         -0.03844     -0.04984      0.93852        0.137
     CHEM1         0.07035      0.08559      0.82655        0.406
     CHEM2         0.07035      0.08559      0.82655        0.406
     PHY1          0.00778      0.00947      0.82717        0.005
     PHY2          0.00778      0.00947      0.82717        0.005
     BYNDALG       0.07341      0.07069      0.51766        0.276

                          SUMMARY TABLE

     VARIABLE         MULTIPLE R   R SQUARE   RSQ CHANGE    SIMPLE R

     CATREAD           0.57425     0.32977     0.32977      0.57425
     SMELSC2           0.62964     0.39645     0.06668      0.37373
     CATMATH           0.66455     0.44163     0.04518      0.55825
```

TABLE 56

Sample Two Clackamas High School Multiple Regression of 18 Variables on SPCT Scores with Reading Achievement Removed

```
                         MULTIPLE R           0.63057
                         R SQUARE             0.39762
                         ADJUSTED R SQUARE    0.36535
                         STANDARD ERROR       2.60061


ANALYSIS OF VARIANCE     DF    SUM OF SQUARES   MEAN SQUARE        F
REGRESSION               3.        249.99624      83.33208    12.32147
RESIDUAL                56.        378.73709       6.76316


     ---------------- VARIABLES IN THE EQUATION ------------------

     VARIABLE            B            BETA      STD ERROR B       F

     CATMATH     0.1428647         0.36061       0.05564        6.592
     SMELSC2      1.690782         0.24297       0.74529        5.147
     CATLANG     0.9349622D-01     0.20978       0.06228        2.254
     (CONSTANT) -0.8040989


       ------------ VARIABLES NOT IN THE EQUATION -------------

       VARIABLE        BETA IN      PARTIAL   TOLERANCE         F

       SEX             0.07639      0.08907    0.81890        0.446
       AGE             0.06153      0.07493    0.89344        0.311
       ELECSCI        -0.01476     -0.01151    0.36602        0.007
       TYPESC1        -0.03552     -0.04564    0.99424        0.115
       TYPESC3         0.03552      0.04564    0.99424        0.115
       SMELSC4        -0.05082     -0.06350    0.94043        0.223
       SMELSC6         0.13135      0.15702    0.86066        1.390
       SMELSC8        -0.12590     -0.15862    0.95614        1.419
       BIO1           -0.04713     -0.05887    0.94003        0.191
       BIO2           -0.04713     -0.05887    0.94003        0.191
       CHEM1           0.11684      0.13634    0.82015        1.042
       CHEM2           0.11684      0.13634    0.82015        1.042
       PHY1            0.01992      0.02327    0.82228        0.030
       PHY2            0.01992      0.02327    0.82228        0.030
       BYNDALG         0.12290      0.11586    0.53530        0.748


                          SUMMARY TABLE

       VARIABLE        MULTIPLE R  R SQUARE  RSQ CHANGE    SIMPLE R

       CATMATH          0.55825    0.31164    0.31164      0.55825
       SMELSC2          0.61105    0.37338    0.06174      0.37373
       CATLANG          0.63057    0.39762    0.02424      0.50294
```

Milwaukie High School

Table 57 presents the results of the multiple regression analysis of Sample Two Milwaukie High School SPCT scores. The regression equation contained two predictor variables that together accounted for 49.17 percent of the variance. The F-value for the equation was 42.07 with 2 and 87 degrees of freedom, which was significant at $p < .001$.

The most important predictor variable was mathematics achievement, which accounted for 46.16 percent of the variance. The other predictor variable in the equation was six semesters of elective science, which accounted for 3.01 percent of the variance.

Removal of the most important predictor variable, mathematics achievement, from the list of independent variables and repetition of the multiple regression analysis produced the results found in table 58. The new regression equation contained three predictor variables that collectively accounted for 44.37 percent of the variance. The F-value for the equation was 22.86 with 3 and 86 degrees of freedom, which was significant at $p < .001$.

The most important predictor variable was reading achievement, which accounted for 37.16 percent of the variance. The other two predictor variables were mathematics beyond algebra and language achievement, which accounted for 4.05 and 3.16 percent of the variance, respectively.

TABLE 57

Sample Two Milwaukie High School Multiple Regression of 22 Variables on SPCT Scores

```
                        MULTIPLE R            0.70118
                        R SQUARE              0.49165
                        ADJUSTED R SQUARE     0.47997
                        STANDARD ERROR        2.59872


ANALYSIS OF VARIANCE       DF     SUM OF SQUARES    MEAN SQUARE          F
REGRESSION                  2.         568.24916      284.12458     42.07177
RESIDUAL                   87.         587.53973        6.75333


   -------------- VARIABLES IN THE EQUATION ---------------

   VARIABLE            B              BETA      STD ERROR B          F

   CATMATH     0.2694006           0.64434        0.03261       68.266
   SMELSC6      3.077090           0.17695        1.35610        5.149
   (CONSTANT)  -3.193173


    ----------- VARIABLES NOT IN THE EQUATION -------------

    VARIABLE      BETA IN      PARTIAL    TOLERANCE           F

    CATREAD       0.17598      0.15883      0.41410       2.226
    CATLANG       0.17682      0.17088      0.47475       2.587
    SEX           0.02658      0.03677      0.97337       0.116
    AGE          -0.02453     -0.03361      0.95420       0.097
    ELECSCI       0.10724      0.13902      0.85431       1.695
    TYPESC1      -0.03353     -0.04523      0.92465       0.176
    TYPESC2      -0.07735     -0.10775      0.98048       1.010
    TYPESC3       0.05680      0.07686      0.93059       0.511
    TYPESC4       0.13078      0.18136      0.97766       2.925
    SMELSC1      -0.06391     -0.08883      0.96189       0.664
    SMELSC2       0.07633      0.10293      0.92442       0.921
    SMELSC4       0.03667      0.05085      0.97735       0.223
    SMELSC7       0.11839      0.16584      0.99751       2.432
    BIO1          0.05482      0.06203      0.65087       0.332
    BIO2          0.01232      0.01450      0.70329       0.018
    CHEM1         0.05678      0.07014      0.77551       0.425
    CHEM2         0.05678      0.07014      0.77551       0.425
    PHY1          0.09651      0.12964      0.91736       1.470
    PHY2          0.09651      0.12964      0.91736       1.470
    BYNDALG       0.13917      0.14528      0.55394       1.854


                           SUMMARY TABLE

    VARIABLE         MULTIPLE R   R SQUARE   RSQ CHANGE    SIMPLE R

    CATMATH            0.67939     0.46157     0.46157      0.67939
    SMELSC6            0.70118     0.49165     0.03008      0.30459
```

TABLE 58

Sample Two Milwaukie High School Multiple Regression of
21 Variables on SPCT Scores with
Mathematics Achievement Removed

```
                         MULTIPLE R            0.66609
                         R SQUARE              0.44368
                         ADJUSTED R SQUARE     0.42427
                         STANDARD ERROR        2.73435


ANALYSIS OF VARIANCE      DF     SUM GF SQUARES    MEAN SQUARE        F
REGRESSION                3.         512.79634      170.93211     22.86210
RESIDUAL                 86.         642.99255        7.47606


   --------------- VARIABLES IN THE EQUATION ------------------

   VARIABLE           B              BETA      STD ERROR B        F

   CATREAD     0.9391654D-01       0.20787       0.06748         1.937
   BYNDALG      1.917902           0.26753       0.74516         6.625
   CATLANG     0.1221015           0.29268       0.05522         4.889
   (CONSTANT)  -1.119376

    ------------ VARIABLES NOT IN THE EGUATION --------------

    VARIABLE       BETA IN      PARTIAL    TOLERANCE           F

    SEX            0.00173      0.00223     0.92331          0.000
    AGE            0.02379      0.03027     0.90073          0.078
    ELECSCI        0.09892      0.12148     0.83907          1.275
    TYPESC1        0.00623      0.00828     0.98406          0.006
    TYPESC2       -0.09367     -0.12185     0.94147          1.281
    TYPESC3        0.04126      0.05427     0.96231          0.251
    TYPESC4        0.08595      0.11238     0.95097          1.087
    SMELSC1       -0.04119     -0.05404     0.95774          0.249
    SMELSC2        0.04581      0.05966     0.94367          0.304
    SMELSC4       -0.01487     -0.01949     0.95483          0.032
    SMELSC6        0.12693      0.16046     0.88902          2.245
    SMELSC7        0.05561      0.07294     0.95706          0.455
    BIO1           0.02215      0.02774     0.87226          0.065
    BIO2           0.00274      0.00355     0.93179          0.001
    CHEM1          0.06765      0.07880     0.75471          0.531
    CHEM2          0.06765      0.07880     0.75471          0.531
    PHY1           0.12894      0.16434     0.90372          2.359
    PHY2           0.12894      0.16434     0.90372          2.359
                            SUMMARY TABLE

    VARIABLE        MULTIPLE R   R SQUARE   RSQ CHANGE    SIMPLE R

    CATREAD           0.60958     0.37158     0.37158      0.60958
    BYNDALG           0.64191     0.41205     0.04047      0.54156
    CATLANG           0.66609     0.44368     0.03163      0.58795
```

Rex Putnam High School

Table 59 presents the results of the multiple regression analysis of the Sample Two Rex Putnam High School SPCT scores. The regression equation contains four predictor variables that collectively accounted for 70.43 percent of the variance. The F-value for the equation was 32.15 with 4 and 54 degrees of freedom, which was significant at $p < .001$.

The most important predictor variable was reading achievement, which accounted for 52.00 percent of the variance. The other predictor variables, in decreasing order of importance, were chemistry, sex, and mathematics achievement. Males had significantly higher scores than females.

Removal of the most important predictor variable, reading achievement, from the list of independent variables and repetition of the multiple regression analysis produced the results found in table 60. The new regression equation contained six variables that collectively accounted for 72.89 percent of the variance. The F-value for the equation was 23.31 with 6 and 52 degrees of freedom, which was significant at $p < .001$.

The most important predictor variable was mathematics achievement, which accounted for 42.45 percent of the variance. The other predictor variables, in decreasing order of importance, were language achievement, sex, chemistry, one semester of physics, and one semester of chemistry.

The unusually large percentage of SPCT variance accounted for by each of these regression equations is worthy of comment. It is reasonable to infer that student scores were reflecting levels of science process skill knowledge commensurate with their achievement level in reading and mathematics. The science instruction, both at the required and elective level, at Rex Putnam High School had effectively provided the opportunity for this learning to occur.

TABLE 59

Sample Two Rex Putnam High School Multiple Regression of 23 Variables on SPCT Scores

```
                         MULTIPLE R             0.83921
                         R SQUARE               0.70428
                         ADJUSTED R SQUARE      0.68237
                         STANDARD ERROR         2.59500


ANALYSIS OF VARIANCE     DF    SUM OF SQUARES    MEAN SQUARE         F
REGRESSION               4.         866.02386      216.50597    32.15107
RESIDUAL                54.         363.63716        6.73402


     ---------------- VARIABLES IN THE EQUATION ------------------

     VARIABLE          B                 BETA      STD ERROR B        F

     CATREAD     0.2277007             0.47935       0.04377       27.060
     CHEM2        2.489729             0.26112       0.84378        8.707
     SEX          2.319960             0.25111       0.68649       11.421
     CATMATH     0.8759192D-01         0.20926       0.04236        4.276
     (CONSTANT)  -5.441268


       -------------- VARIABLES NOT IN THE EQUATION ---------------

       VARIABLE        BETA IN      PARTIAL    TOLERANCE          F

       CATLANG         0.21014      0.23016      0.35474        2.965
       AGE            -0.01092     -0.01919      0.91321        0.020
       ELECSCI         0.02979      0.03589      0.42926        0.068
       TYPESC3         0.04650      0.08345      0.95237        0.372
       TYPESC4        -0.04650     -0.08345      0.95237        0.372
       SMELSC1        -0.07045     -0.12725      0.96470        0.872
       SMELSC2         0.04022      0.07312      0.97724        0.285
       SMELSC3         0.03937      0.06865      0.89911        0.251
       SMELSC4        -0.05377     -0.08282      0.70152        0.366
       SMELSC5        -0.05670     -0.09448      0.82111        0.477
       SMELSC6         0.03971      0.06891      0.89057        0.253
       SMELSC8         0.08324      0.14797      0.93438        1.186
       BIO1           -0.04384     -0.07363      0.83438        0.289
       BIO2           -0.02059     -0.03376      0.79530        0.060
       CHEM1          -0.29355     -0.14142      0.06664        1.082
       PHY1            0.11273      0.16697      0.64672        1.520
       PHY2            0.10635      0.16191      0.68544        1.427
       ADVCHEM1        0.02520      0.04056      0.76607        0.067
       BYNDALG         0.04014      0.04726      0.41000        0.119
                              SUMMARY TABLE

       VARIABLE      MULTIPLE R  R SQUARE  RSQ CHANGE   SIMPLE R

       CATREAD         0.72111    0.52000    0.52000     0.72111
       CHEM2           0.78366    0.61412    0.09412     0.56066
       SEX             0.82514    0.68086    0.06674     0.30218
       CATMATH         0.83921    0.70428    0.02342     0.65150
```

TABLE 60

Sample Two Rex Putnam High School Multiple Regression of 22 Variables on SPCT Scores with CAT Reading Achievement Removed

```
                            MULTIPLE R              0.85378
                            R SQUARE                0.72894
                            ADJUSTED R SQUARE       0.69766
                            STANDARD ERROR          2.53176


ANALYSIS OF VARIANCE        DF      SUM OF SQUARES    MEAN SQUARE         F
REGRESSION                   6.          896.34966      149.39161    23.30663
RESIDUAL                    52.          333.31136        6.40983

     ---------------- VARIABLES IN THE EQUATION ------------------

     VARIABLE            B              BETA      STD ERROR B         F

     CATMATH     0.7151592D-01       0.17086         0.04268        2.808
     CATLANG     0.2581764           0.46276         0.04767       29.331
     SEX          2.877795           0.31149         0.67904       17.961
     CHEM2        7.320739           0.76778         2.68886        7.413
     PHY1         2.519936           0.24035         1.00808        6.249
     CHEM1       -5.485531          -0.58105         2.75866        3.954
     (CONSTANT)  -6.064067

       ------------ VARIABLES NOT IN THE EQUATION ------------

       VARIABLE        BETA IN      PARTIAL     TOLERANCE          F

       AGE             0.00668      0.01199      0.87305         0.007
       ELECSCI        -0.05645     -0.06690      0.35515         0.229
       TYPESC3         0.09636      0.18264      0.97602         1.764
       TYPESC4        -0.09636     -0.18264      0.97602         1.764
       SMELSC1        -0.09442     -0.17803      0.96351         1.669
       SMELSC2         0.04472      0.07881      0.84172         0.319
       SMELSC3         0.04438      0.07986      0.87798         0.326
       SMELSC4        -0.03617     -0.05465      0.61853         0.153
       SMELSC5        -0.13419     -0.21093      0.86969         2.375
       SMELSC6        -0.01063     -0.01827      0.60093         0.017
       SMELSC8         0.10756      0.19840      0.92300         2.091
       BIO1           -0.04465     -0.07831      0.83369         0.315
       BIO2           -0.01229     -0.02116      0.80345         0.023
       PHY2           -0.06117     -0.05853      0.24812         0.175
       ADVCHEM1        0.03768      0.06275      0.75184         0.202
       BYNDALG         0.02282      0.02728      0.38751         0.038
                              SUMMARY TABLE

       VARIABLE        MULTIPLE R   R SQUARE   RSQ CHANGE     SIMPLE R

       CATMATH          0.65150     0.42445     0.42445       0.65150
       CATLANG          0.73676     0.54281     0.11836       0.62847
       SEX              0.78862     0.62192     0.07912       0.30218
       CHEM2            0.82976     0.68850     0.06658       0.56066
       PHY1             0.84162     0.70833     0.01982       0.47690
       CHEM1            0.85378     0.72894     0.02061       0.53769
```

Summary

The multiple regression analysis of Sample Two data by schools again revealed a strong relationship between academic achievement and SPCT scores. This relationship was especially strong for reading and mathematics achievement. At Clackamas and Milwaukie High Schools, having completed two or six semesters of elective science was a consistent predictor variable. At Rex Putnam High School, specific elective courses entered the equations as stronger predictors than having "elected science" or "elected a certain number of semesters of science." Chemistry was the most important elective course, followed by physics.

Sex was only a predictor variable at Rex Putnam High School. Sex was reasonably strong, accounting for approximately seven percent of the variance, and favored males.

No first-level science course entered any of the regression equations. At Rex Putnam, however, this would be expected since all students complete the same first-level course. Of particular interest is the absence of biology as a predictor variable either in the role of a first-level course or elective science course.

SPCT Differences Between Schools

Possible significant adjusted SPCT score differences between schools were assessed by the use of the analysis of covariance (ANCOVA) procedure. Table 61 presents the results of the ANCOVA of SPCT scores by school with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The grand mean for Sample Two students was 12.11. The adjusted school means were 12.00 for Clackamas, 11.37 for Milwaukie, and 13.33 for Rex Putnam. Significant differences were indicated at $p < .001$.

Tables 62 through 64 present the results of the ANCOVA of the SPCT scores for all possible pairings of the three schools. Rex Putnam students' SPCT scores were found to be significantly higher than those of both Clackamas students ($p=.004$) and Milwaukie students ($p < .001$).

The findings indicate that the science program composed of a first-level Unified Science course and elective courses at Rex Putnam High School produced students with significantly higher adjusted SPCT scores than the science programs at Clackamas and Milwaukie High Schools.

TABLE 61

Total Sample Two ANCOVA of SPCT Scores by School with
Mathematics Achievement, Reading Achievement,
Language Achievement, Sex, and Age
as Covariates

```
                           SUM OF                MEAN              SIGNIF
SOURCE OF VARIATION       SQUARES    DF        SQUARE        F       OF F

COVARIATES               1638.287     5       327.657   45.930      0.000
   CATMATH                285.480     1       285.480   40.018      0.000
   CATREAD                 95.475     1        95.475   13.383      0.000
   CATLANG                  9.151     1         9.151    1.283      0.259
   SEX                     37.791     1        37.791    5.297      0.022
   AGE                     12.864     1        12.864    1.803      0.181

MAIN EFFECTS              123.133     2        61.567    8.630      0.000
   ID                     123.133     2        61.567    8.630      0.000

EXPLAINED                1761.420     7       251.631   35.273      0.000

RESIDUAL                 1441.037   202         7.134

TOTAL                    3202.458   209        15.323




GRAND MEAN =     12.11                               ADJUSTED FOR
                                                     INDEPENDENTS
                                       UNADJUSTED    + COVARIATES
VARIABLE + CATEGORY          N         DEV'N   ETA   DEV'N    BETA

ID
    1 CLACKAMAS             60          0.32         -0.11
    2 MILWAUKIE             90         -0.92         -0.74
    3 PUTNAM                60          1.06          1.22
                                               0.22             0.21

MULTIPLE R SQUARED                                              0.550
MULTIPLE R                                                      0.742
```

TABLE 62

Sample Two ANCOVA on SPCT Scores by Clackamas and Rex Putnam High Schools with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	1036.796	5	207.359	28.785	0.000
CATMATH	152.551	1	152.551	21.177	0.000
CATREAD	87.884	1	87.884	12.200	0.001
CATLANG	3.820	1	3.820	0.530	0.468
SEX	55.080	1	55.080	7.646	0.007
AGE	1.485	1	1.485	0.206	0.651
MAIN EFFECTS	62.374	1	62.374	8.659	0.004
ID	62.374	1	62.374	8.659	0.004
EXPLAINED	1099.170	6	183.195	25.431	0.000
RESIDUAL	814.020	113	7.204		
TOTAL	1913.190	119	16.077		

GRAND MEAN = 12.80

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
ID					
1 CLACKAMAS	60	-0.37		-0.78	
3 PUTNAM	60	0.37		0.78	
			0.09		0.20
MULTIPLE R SQUARED					0.575
MULTIPLE R					0.758

TABLE 63

Sample Two ANCOVA on SPCT Scores by Milwaukie and Rex Putnam High Schools with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

```
                          SUM OF              MEAN                SIGNIF
SOURCE OF VARIATION      SQUARES     DF      SQUARE         F      OF F

COVARIATES              1391.750      5     278.350    37.713     0.000
   CATMATH               263.930      1     263.930    35.759     0.000
   CATREAD                65.421      1      65.421     8.864     0.003
   CATLANG                 8.244      1       8.244     1.117     0.292
   SEX                    32.119      1      32.119     4.352     0.039
   AGE                    14.373      1      14.373     1.947     0.165

MAIN EFFECTS             117.717      1     117.717    15.949     0.000
   ID                    117.716      1     117.716    15.949     0.000

EXPLAINED               1509.466      6     251.578    34.085     0.000

RESIDUAL                1055.457    143       7.381

TOTAL                   2564.923    149      17.214



GRAND MEAN =     11.98                                 ADJUSTED FOR
                                                       INDEPENDENTS
                                       UNADJUSTED      + COVARIATES
VARIABLE + CATEGORY          N         DEV'N   ETA     DEV'N    BETA

ID
     2 MILWAUKIE            90         -0.79           -0.78
     3 PUTNAM               60          1.19            1.17
                                               0.23              0.23

MULTIPLE R SQUARED                                               0.589
MULTIPLE R                                                       0.767
```

TABLE 64

Sample Two ANCOVA on SPCT Scores by Clackamas and Milwaukie High Schools with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	850.582	5	170.116	25.029	0.000
CATMATH	113.944	1	113.944	16.764	0.000
CATREAD	37.926	1	37.926	5.580	0.020
CATLANG	10.890	1	10.890	1.602	0.208
SEX	8.636	1	8.636	1.271	0.262
AGE	4.063	1	4.063	0.598	0.441
MAIN EFFECTS	17.724	1	17.724	2.608	0.109
ID	17.724	1	17.724	2.608	0.109
EXPLAINED	868.306	6	144.718	21.292	0.000
RESIDUAL	971.951	143	6.797		
TOTAL	1840.257	149	12.351		

GRAND MEAN = 11.69

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
ID					
1 CLACKAMAS	60	0.75		0.45	
2 MILWAUKIE	90	-0.50		-0.30	
			0.17		0.10
MULTIPLE R SQUARED					0.472
MULTIPLE R					0.687

Analysis of SPCT Scores for Students Electing No Science

Total sample

Table 65 presents the results of an ANCOVA of Sample Two student SPCT scores for those students who elected no science after the required year. The ANCOVA was for SPCT scores by year with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean of the SPCT scores for the 121 students who had not elected any science was 10.66. The unadjusted means for each of the grade levels were 10.83 for the 10th grade, 10.55 for the 11th grade, and 10.72 for the 12th grade. The differences between the unadjusted means were not significant at $p \leq .05$. The adjusted means for each grade level were 10.52 for the 10th grade (N=24), 10.57 for the 11th grade (N=54), and 10.85 for the 12th grade (N=43). The differences between the adjusted means were not significant at $p \leq .05$.

Clackamas High School

Table 66 presents the results of an ANCOVA of the Sample Two Clackamas High School student SPCT scores by year with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean for the 33 Clackamas students not electing any science after the required year was 11.33. The unadjusted means for each grade level were 11.16 for the 11th grade and 11.57 for the 12th grade. The difference between the unadjusted means was not significant at $p \leq .05$. The adjusted means for each grade level were 11.68 for the 11th grade (N=19) and 10.85 for the 12th grade (N=14). The difference between the adjusted means was not significant at $p \leq .05$.

Milwaukie High School

Table 67 presents the results of an ANCOVA of the Sample Two Milwaukie High School student SPCT scores by year with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean for the 58 Milwaukie students not electing any science after the required year was 10.29. The unadjusted means for each grade level were 10.83 for the 10th grade, 9.90 for the 11th grade, and 10.00 for the 12th grade. The differences between the unadjusted means were not significant at $p \leq .05$. The adjusted means for each of the grade levels were 9.99 for the 10th grade (N=23), 10.12 for the 11th grade (N=20), and 10.97 for the 12th grade (N=15). The differences between adjusted means were not significant at $p \leq .05$.

Rex Putnam High School

Table 68 presents the results of an ANCOVA of the Sample Two Rex Putnam High School student SPCT scores by year with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean for the 30 Rex Putnam students not electing any science after the required year was 10.63. The unadjusted means for each grade level were 10.63 for the 11th grade and 10.64 for the 12th grade. The difference between the unadjusted means was not significant at $p \leq .05$. The adjusted means for each grade level were 10.56 for the 11th grade (N=16) and 10.55 for the 12th grade (N=14). The difference between the adjusted means was not significant at $p \leq .05$.

Summary

No significant differences at $p \leq .05$ were found between either the unadjusted or adjusted SPCT scores of students at different grade levels who had elected no science after their required year. This was found to be the case for the total sample as well as within each of the three schools.

TABLE 65

Sample Two Students Not Electing Science ANCOVA by Year with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	447.451	5	89.490	11.054	0.000
CATMATH	57.534	1	57.534	7.107	0.009
CATREAD	10.237	1	10.237	1.265	0.263
CATLANG	34.635	1	34.635	4.278	0.041
AGE	2.902	1	2.902	0.358	0.551
SEX	19.329	1	19.329	2.388	0.125
MAIN EFFECTS	0.862	2	0.431	0.053	0.948
YEAR	0.862	2	0.431	0.053	0.948
EXPLAINED	448.314	7	64.045	7.911	0.000
RESIDUAL	914.781	113	8.095		
TOTAL	1363.095	120	11.359		

GRAND MEAN = 10.66

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
YEAR					
0 GRADE 10	24	0.30		-0.14	
1 GRADE 11	54	-0.18		-0.09	
2 GRADE 12	43	0.06		0.19	
			0.05		0.04
MULTIPLE R SQUARED					0.329
MULTIPLE R					0.573

TABLE 66

Sample Two Clackamas High School Students Not Electing Science ANCOVA by Year with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	47.892	5	9.578	1.210	0.332
CATMATH	11.932	1	11.932	1.507	0.231
CATREAD	5.600	1	5.600	0.707	0.408
CATLANG	10.057	1	10.057	1.270	0.270
AGE	15.677	1	15.677	1.980	0.171
SEX	5.443	1	5.443	0.687	0.415
MAIN EFFECTS	1.598	1	1.598	0.202	0.657
YEAR	1.598	1	1.598	0.202	0.657
EXPLAINED	49.490	6	8.248	1.042	0.422
RESIDUAL	205.843	26	7.917		
TOTAL	255.333	32	7.979		

GRAND MEAN = 11.33

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
YEAR					
1 GRADE 11	19	-0.18		0.35	
2 GRADE 12	14	0.24		-0.48	
			0.07		0.15
MULTIPLE R SQUARED					0.194
MULTIPLE R					0.440

TABLE 67

Sample Two Milwaukie High School Students Not Electing Science ANCOVA of SPCT Scores by Year with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	300.892	5	60.178	7.207	0.000
CATMATH	92.699	1	92.699	11.102	0.002
CATREAD	0.198	1	0.198	0.024	0.878
CATLANG	8.955	1	8.955	1.072	0.305
AGE	0.554	1	0.554	0.066	0.798
SEX	3.008	1	3.008	0.360	0.551
MAIN EFFECTS	3.622	2	1.811	0.217	0.806
YEAR	3.621	2	1.811	0.217	0.806
EXPLAINED	304.514	7	43.502	5.210	0.000
RESIDUAL	417.499	50	8.350		
TOTAL	722.012	57	12.667		

GRAND MEAN = 10.29

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
YEAR					
0	23	0.53		-0.30	
1	20	-0.39		-0.17	
2	15	-0.29		0.68	
			0.12		0.12
MULTIPLE R SQUARED					0.422
MULTIPLE R					0.649

TABLE 68

Sample Two Rex Putnam High School Students Not Electing Science
ANCOVA of SPCT Scores by Year with Mathematics Achievement,
Reading Achievement, Language Achievement, Sex, and Age
as Covariates

```
                         SUM OF            MEAN                 SIGNIF
SOURCE OF VARIATION      SQUARES   DF     SQUARE        F        OF F

COVARIATES               221.683    5     44.337     7.122     0.000
   CATMATH                 0.000    1      0.000     0.000     0.997
   CATREAD                18.968    1     18.968     3.047     0.095
   CATLANG                 9.422    1      9.422     1.513     0.232
   AGE                     0.456    1      0.456     0.073     0.789
   SEX                    49.978    1     49.978     8.028     0.010

MAIN EFFECTS               4.318    2      2.159     0.347     0.711
   YEAR                    4.318    2      2.159     0.347     0.711

EXPLAINED                226.001    7     32.286     5.186     0.001

RESIDUAL                 136.965   22      6.226

TOTAL                    362.966   29     12.516




GRAND MEAN =     10.63                           ADJUSTED FOR
                                                 INDEPENDENTS
                                    UNADJUSTED   + COVARIATES
VARIABLE + CATEGORY         N      DEV'N  ETA    DEV'N   BETA

YEAR
     0 GRADE 10             1       3.37          2.19
     1 GRADE 11            15      -0.23         -0.07
     2 GRADE 12            14       0.01         -0.08
                                          0.18            0.12

MULTIPLE R SQUARED                                        0.623
MULTIPLE R                                                0.789
```

Analysis of SPCT Scores for Students Electing Science

Total Sample

Table 69 presents the results of an ANCOVA of the total Sample Two student SPCT scores for those students who elected science after the required year. The ANCOVA was for the SPCT scores by year with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean of the SPCT scores for the 89 students electing science was 14.08. The unadjusted means for each grade level were 13.29 for the 10th grade, 13.89 for the 11th grade, and 14.34 for the 12th grade. The differences between the unadjusted means were not significant at $p \leq .05$. The adjusted means for each grade level were 12.87 for the 10th grade (N=7), 14.07 for the 11th grade (N=35), and 14.27 for the 12th grade (N=47). The differences between the adjusted means were not significant at $p \leq .05$.

Clackamas High School

Table 70 presents the results of an ANCOVA of the Sample Two Clackamas High School student SPCT scores by year with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean for the 27 Clackamas students who elected science after the required year was 13.78. The unadjusted means for each grade level were 14.18 for the 11th grade and 13.50 for the 12th grade. The difference between the unadjusted means was not significant at $p \leq .05$. The adjusted means for each grade level were 13.94 for the 11th grade (N=11) and 13.67 for the 12th grade (N=16). The difference between the adjusted means was not significant at $p \leq .05$.

Milwaukie High School

Table 71 presents the results of an ANCOVA of the Sample Two Milwaukie High School student SPCT scores by year with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean for the 32 Milwaukie students who elected science after the required year was 12.81. The unadjusted means for each grade level were 13.29 for the 10th grade, 12.30 for the 11th grade, and 12.93 for the 12th grade. The difference between the unadjusted means was not significant at $p \leq .05$. The adjusted means for each of the grade level were 14.33 for the 10th grade (N=7), 13.18 for the 11th grade (N=10), and 11.85 for the 12th grade (N=15). The differences between the adjusted means were not significant at $p \leq .05$.

Rex Putnam High School

Table 72 presents the results of an ANCOVA of the Sample Two Rex Putnam High School student SPCT scores by year with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean for the 30 Rex Putnam students electing science after the required year was 15.70. The unadjusted means for each of the grade levels were 14.74 for the 11th grade and

16.50 for the 12th grade. The difference between the unadjusted means was not significant at $p \leq .05$. The adjusted means for each of the grade levels were 14.71 for the 11th grade (N=14) and 16.56 for the 12th grade (N=16). The difference between the adjusted means was not significant at $p \leq .05$.

Summary

No significant differences at $p \leq .05$ were found between either the unadjusted or adjusted SPCT scores of Sample Two students at different grade levels who had elected science after their required year. This was found to be the case for the total sample as well as within each of the three schools.

TABLE 69

Sample Two Students Electing Science ANCOVA by Year with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	713.340	5	142.668	22.126	0.000
CATMATH	162.301	1	162.301	25.171	0.000
CATREAD	85.861	1	85.861	13.316	0.000
CATLANG	3.544	1	3.544	0.550	0.461
AGE	3.812	1	3.812	0.591	0.444
SEX	11.777	1	11.777	1.827	0.180
MAIN EFFECTS	4.818	2	2.409	0.374	0.689
YEAR	4.819	2	2.409	0.374	0.689
EXPLAINED	718.158	7	102.594	15.911	0.000
RESIDUAL	522.284	81	6.448		
TOTAL	1240.442	88	14.096		

GRAND MEAN = 14.08

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
YEAR					
0 GRADE 10	7	-0.79		-1.21	
1 GRADE 11	35	-0.19		-0.01	
2 GRADE 12	47	0.26		0.19	
			0.08		0.10
MULTIPLE R SQUARED					0.579
MULTIPLE R					0.761

TABLE 70

Sample Two Clackamas High School Students Electing Science ANCOVA by Year with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	192.633	5	38.527	8.380	0.000
CATMATH	0.448	1	0.448	0.097	0.758
CATREAD	49.151	1	49.151	10.691	0.004
CATLANG	1.498	1	1.498	0.326	0.574
AGE	0.291	1	0.291	0.063	0.804
SEX	5.737	1	5.737	1.248	0.277
MAIN EFFECTS	0.084	1	0.084	0.018	0.894
YEAR	0.084	1	0.084	0.018	0.894
EXPLAINED	192.717	6	32.119	6.986	0.000
RESIDUAL	91.950	20	4.597		
TOTAL	284.666	26	10.949		

GRAND MEAN = 13.78

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
YEAR					
1 GRADE 11	11	0.40		0.16	
2 GRADE 12	16	-0.28		-0.11	
			0.10		0.04
MULTIPLE R SQUARED					0.677
MULTIPLE R					0.823

TABLE 71

Sample Two Milwaukie High School Students Electing Science ANCOVA by Year with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	176.378	5	35.276	6.855	0.000
CATMATH	7.688	1	7.688	1.494	0.233
CATREAD	20.175	1	20.175	3.921	0.059
CATLANG	3.401	1	3.401	0.661	0.424
AGE	0.577	1	0.577	0.112	0.741
SEX	3.140	1	3.140	0.610	0.442
MAIN EFFECTS	3.001	2	1.500	0.292	0.750
YEAR	3.001	2	1.500	0.292	0.750
EXPLAINED	179.379	7	25.626	4.980	0.001
RESIDUAL	123.496	24	5.146		
TOTAL	302.875	31	9.770		

GRAND MEAN = 12.81

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
YEAR					
0	7	0.47		1.52	
1	10	-0.51		0.37	
2	15	0.12		-0.96	
			0.12		0.32
MULTIPLE R SQUARED					0.592
MULTIPLE R					0.770

TABLE 72

Sample Two Rex Putnam High School Students Electing Science ANCOVA by Year with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	358.088	5	71.618	10.706	0.000
CATMATH	111.434	1	111.434	16.658	0.000
CATREAD	24.523	1	24.523	3.666	0.068
CATLANG	6.455	1	6.455	0.965	0.336
AGE	4.579	1	4.579	0.684	0.417
SEX	24.442	1	24.442	3.654	0.068
MAIN EFFECTS	8.349	1	8.349	1.248	0.275
YEAR	8.349	1	8.349	1.248	0.275
EXPLAINED	366.437	6	61.073	9.130	0.000
RESIDUAL	153.860	23	6.690		
TOTAL	520.297	29	17.941		

GRAND MEAN = 15.70

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
YEAR					
1 GRADE 11	14	-0.91		-0.99	
2 GRADE 12	16	0.80		0.86	
			0.21		0.22
MULTIPLE R SQUARED					0.704
MULTIPLE R					0.839

Analysis of SPCT Scores Comparing Students Who Elected Science and Students Who Did Not Elect Science

Total sample

Table 73 presents the results of an ANCOVA of the total Sample Two student SPCT scores comparing students who elected science to those who did not. The ANCOVA was for the SPCT scores by electing science with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The grand unadjusted mean for Sample Two students was 12.11. The unadjusted mean for the 89 students who had elected science was 14.08, and the unadjusted mean for the 121 students who had not elected science was 10.66. The difference between the unadjusted means was significant at $p < .001$. The adjusted mean for the 89 students who had elected science was 12.75, while the adjusted mean for the 121 students who had not elected science was 11.64. The difference between the adjusted means was significant at $p = .011$.

Clackamas High School

Table 74 presents the results of an ANCOVA of the Sample Two Clackamas High School student SPCT scores by electing science with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean for all Clackamas students was 12.43. The unadjusted mean for the 27 students electing science was 13.78, and the unadjusted mean for the 33 students not electing science was 11.33. The difference between the unadjusted means was significant at $p < .002$. The adjusted mean for the 27 students who had elected science was 12.93, while the adjusted mean for the 33 students who had not elected science was 12.02. The difference between the two adjusted means was not significant at $p \leq .05$.

Milwaukie High School

Table 75 presents the results of an ANCOVA of the Sample Two Milwaukie High School student SPCT scores by electing science with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean for all Sample Two Milwaukie students was 11.19. The unadjusted mean for the 32 students who had elected science was 12.81, and the unadjusted mean for the 58 students who had not elected science was 10.29. The difference between the unadjusted means was significant at $p < .001$. The adjusted mean for the 32 students who had elected science was 11.74, while the adjusted mean for the 58 students who had not elected science was 10.89. The difference between the adjusted means was not significant at $p \leq .05$.

Rex Putnam High School

Table 76 presents the results of an ANCOVA of the Sample Two Rex Putnam High School student SPCT scores by electing science with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean for all Rex Putnam students in Sample Two was 13.17. The unadjusted mean for the 30 students who had elected science was 15.70, and the unadjusted mean for the 30 students who had not elected science was 10.64. The difference between the unadjusted means was significant at $p < .001$. The adjusted mean for the students who had elected science was 13.94, while the adjusted mean for the students who had not elected science was 12.40. The difference between the adjusted means was not significant at $p \leq .05$.

TABLE 73

Sample Two Students ANCOVA by Electing Science with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

```
                         SUM OF          MEAN               SIGNIF
SOURCE OF VARIATION     SQUARES   DF    SQUARE        F      OF F

COVARIATES             1638.310    5   327.662   43.921     0.000
   CATMATH              285.491    1   285.491   38.266     0.000
   CATREAD               95.477    1    95.477   12.798     0.000
   CATLANG                9.149    1     9.149    1.226     0.269
   AGE                   12.863    1    12.863    1.724     0.191
   SEX                   37.792    1    37.792    5.066     0.025

MAIN EFFECTS             49.706    1    49.706    6.663     0.011
   ELECSCI               49.706    1    49.706    6.663     0.011

EXPLAINED              1688.015    6   281.336   37.711     0.000

RESIDUAL               1514.444  203     7.460

TOTAL                  3202.460  209    15.323




GRAND MEAN =     12.11                              ADJUSTED FOR
                                                    INDEPENDENTS
                                      UNADJUSTED    + COVARIATES
VARIABLE + CATEGORY              N    DEV'N   ETA   DEV'N   BETA

ELECSCI
    0 NO ELECTIVE SCIENCE      121   -1.45          -0.47
    1 ELECTIVE SCIENCE          89    1.97           0.64
                                              0.43           0.14

MULTIPLE R SQUARED                                          0.527
MULTIPLE R                                                  0.726
```

TABLE 74

Sample Two Clackamas High School Students ANCOVA by Electing Science with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	256.464	5	51.293	7.492	0.000
CATMATH	21.209	1	21.209	3.098	0.084
CATREAD	28.457	1	28.457	4.156	0.046
CATLANG	2.754	1	2.754	0.402	0.529
AGE	0.761	1	0.761	0.111	0.740
SEX	8.626	1	8.626	1.260	0.267
MAIN EFFECTS	9.394	1	9.394	1.372	0.247
ELECSCI	9.394	1	9.394	1.372	0.247
EXPLAINED	265.857	6	44.310	6.472	0.000
RESIDUAL	362.871	53	6.847		
TOTAL	628.728	59	10.656		

GRAND MEAN = 12.43

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
ELECSCI					
0 NO ELECTIVE SCIENCE	33	-1.10		-0.41	
1 ELECTIVE SCIENCE	27	1.34		0.50	
			0.38		0.14
MULTIPLE R SQUARED					0.423
MULTIPLE R					0.650

TABLE 75

Sample Two Milwaukie High School Students ANCOVA by Electing Science with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	570.021	5	114.004	16.505	0.000
CATMATH	104.572	1	104.572	15.140	0.000
CATREAD	9.317	1	9.317	1.349	0.249
CATLANG	5.974	1	5.974	0.865	0.355
SEX	2.532	1	2.532	0.367	0.547
AGE	0.238	1	0.238	0.034	0.853
MAIN EFFECTS	12.468	1	12.468	1.805	0.183
ELECSCI	12.468	1	12.468	1.805	0.183
EXPLAINED	582.489	6	97.081	14.055	0.000
RESIDUAL	573.291	83	6.907		
TOTAL	1155.780	89	12.986		

GRAND MEAN = 11.19

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
ELECSCI					
0 NO ELECTIVE SCIENCE	58	-0.90		-0.30	
1 ELECTIVE SCIENCE	32	1.62		0.55	
			0.34		0.11

MULTIPLE R SQUARED	0.504
MULTIPLE R	0.710

TABLE 76

Sample Two Rex Putnam High School Students ANCOVA by Electing Science with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	858.207	5	171.641	23.566	0.000
CATMATH	80.248	1	80.248	11.018	0.002
CATREAD	52.229	1	52.229	7.171	0.010
CATLANG	13.232	1	13.232	1.817	0.183
AGE	4.100	1	4.100	0.563	0.456
SEX	73.294	1	73.294	10.063	0.003
MAIN EFFECTS	24.093	1	24.093	3.308	0.075
ELECSCI	24.093	1	24.093	3.308	0.075
EXPLAINED	882.300	6	147.050	20.189	0.000
RESIDUAL	386.028	53	7.284		
TOTAL	1268.327	59	21.497		

GRAND MEAN = 13.17

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
ELECSCI					
0 NO ELECTIVE SCIENCE	30	-2.53		-0.77	
1 ELECTIVE SCIENCE	30	2.53		0.77	
			0.55		0.17

MULTIPLE R SQUARED	0.696
MULTIPLE R	0.834

Tenth grade

Table 77 presents the results of an ANCOVA of the Sample Two tenth-grade student SPCT scores by electing science with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean for all the tenth-grade students was 11.40. The unadjusted mean for the 7 students who had elected science was 13.29, and the unadjusted mean for the 23 students who had not elected science was 10.83. The difference between the unadjusted means was not significant at $p \leq .05$. The adjusted mean for the students who had elected science was 11.79, while the adjusted mean for the students who had not elected science was 11.28. The difference between the adjusted means was not significant at $p \leq .05$.

11th grade

Table 78 presents the results of an ANCOVA of the Sample Two 11th-grade student SPCT scores by electing science with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean for all 11th-grade students was 11.84. The unadjusted mean for the 35 students who had elected science was 13.89. The unadjusted mean for the 55 students who had not elected science was 10.55. The difference between the unadjusted means was significant at $p < .001$. The adjusted mean for the 35 students who had elected science was 12.63, while the adjusted mean for the 55 students who had not elected science was 11.33. The difference between the adjusted means was not significant at $p \leq .05$.

TABLE 77

Sample Two Tenth-Grade Students ANCOVA by Electing Science with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	190.256	5	38.051	4.660	0.004
CATMATH	60.740	1	60.740	7.439	0.012
CATREAD	0.295	1	0.295	0.036	0.851
CATLANG	0.060	1	0.060	0.007	0.933
SEX	17.004	1	17.004	2.082	0.162
AGE	14.573	1	14.573	1.785	0.195
MAIN EFFECTS	1.138	1	1.138	0.139	0.712
ELECSCI	1.138	1	1.138	0.139	0.712
EXPLAINED	191.395	6	31.899	3.907	0.008
RESIDUAL	187.804	23	8.165		
TOTAL	379.198	29	13.076		

GRAND MEAN = 11.40

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
ELECSCI					
0	23	-0.57		-0.12	
1	7	1.89		0.39	
			0.29		0.06
MULTIPLE R SQUARED					0.505
MULTIPLE R					0.710

TABLE 78

Sample Two 11th-Grade Students ANCOVA by Electing Science with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	687.304	5	137.461	17.122	0.000
CATMATH	43.250	1	43.250	5.387	0.023
CATREAD	50.880	1	50.880	6.337	0.014
CATLANG	9.708	1	9.708	1.209	0.275
SEX	19.149	1	19.149	2.385	0.126
AGE	1.777	1	1.777	0.221	0.639
MAIN EFFECTS	28.153	1	28.153	3.507	0.065
ELECSCI	28.153	1	28.153	3.507	0.065
EXPLAINED	715.457	6	119.243	14.853	0.000
RESIDUAL	666.356	83	8.028		
TOTAL	1381.813	89	15.526		

GRAND MEAN = 11.84

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
ELECSCI					
0	55	-1.30		-0.51	
1	35	2.04		0.79	
			0.42		0.16
MULTIPLE R SQUARED					0.518
MULTIPLE R					0.720

12th grade

Table 79 presents the results of an ANCOVA of the Sample Two 12th-grade students SPCT scores by electing science with mathematics achievement, reading achievement, language achievement, sex, and age as covariates. The unadjusted mean for all Sample Two 12th-grade students was 12.61. The unadjusted mean for the 47 students who had elected science was 14.34, and the unadjusted mean for the 43 students who had not elected science was 10.72. The difference between the unadjusted means was significant at $p < .001$. The adjusted mean for the 47 students who had elected science was 13.08, while the adjusted mean for the 43 students who had not elected science was 12.09. The difference between the adjusted means was not significant at $p \leq .05$.

Summary

A statistically significant ($p = .011$) difference was found between the Sample Two adjusted SPCT mean scores of students who had elected science and those who had not elected science. The students who had elected science had significantly higher SPCT scores than those who had not elected any science after the required year.

No statistically significant ($p \leq .05$) differences were found between the adjusted means of students who had elected science and those students who had not elected science within each of the three schools. However, the unadjusted and adjusted mean scores of students who had elected science were higher in every comparison

TABLE 79

Sample Two 12th-Grade Students ANCOVA by Electing Science with Mathematics Achievement, Reading Achievement, Language Achievement, Sex, and Age as Covariates

```
                          SUM OF            MEAN                SIGNIF
SOURCE OF VARIATION      SQUARES  DF      SQUARE          F       OF F

COVARIATES               794.590   5     158.918     22.512      0.000
   CATMATH               201.856   1     201.856     28.595      0.000
   CATREAD                43.866   1      43.866      6.214      0.015
   CATLANG                 3.195   1       3.195      0.453      0.503
   SEX                     3.524   1       3.524      0.499      0.482
   AGE                     0.413   1       0.413      0.058      0.810

MAIN EFFECTS              16.884   1      16.884      2.392      0.126
   ELECSCI                16.884   1      16.884      2.392      0.126

EXPLAINED                811.474   6     135.246     19.159      0.000

RESIDUAL                 585.908  83       7.059

TOTAL                   1397.382  89      15.701



GRAND MEAN =    12.61                               ADJUSTED FOR
                                                    INDEPENDENTS
                                     UNADJUSTED     + COVARIATES
VARIABLE + CATEGORY          N      DEV'N   ETA     DEV'N    BETA

ELECSCI
   0                        43      -1.89           -0.52
   1                        47       1.73            0.47
                                            0.46               0.13

MULTIPLE R SQUARED                                            0.581
MULTIPLE R                                                    0.762
```

than the comparable mean scores of the students who had not elected science. The unadjusted means were significantly ($p \leq .002$) different in all three schools. The students who had elected science had significantly higher scores than the students who had not elected science.

No statistically significant ($p \leq .05$) differences were found between the adjusted mean scores of students who had elected science and those who had not elected science within each of the grade levels included within Sample Two. However, both the unadjusted and adjusted mean scores of the students who had elected science were higher at all grade levels than the comparable mean scores of the students who had not elected science. The difference between the unadjusted means was significant ($p < .05$) at both the 11th-grade and 12th-grade levels.

Summary Discussion of Sample Two Findings

The most consistent and frequent finding from the analysis of the Sample Two data was the very strong relationship that existed between academic achievement and science process skill competency as measured by the SPCT. Achievement in the areas of mathematics and reading had an especially strong relationship. SPCT variance had greater percentages accounted for by academic achievement than by any other variable. These findings are consistent with those from the analysis of Sample One data; reading achievement, however, was a stronger predictor variable in the Sample Two data than it was for Sample One.

Academic achievement

Mathematics achievement was significant ($p \leq .005$) and the most important predictor variable in four of the initial regression equations, including the equation for the total sample; mathematics achievement accounted for an average of 44.38 percent of the SPCT variance when it was the most important predictor variable. Reading achievement was significant ($p < .001$) and the most important predictor variable in the other three initial regression equations; reading achievement accounted for an average of 42.53 percent of the variance when it was the most important predictor variable. Language achievement did not account for more than two percent of the variance in any of the initial regression equations, but it did emerge as a significant ($p \leq .005$) predictor variable in three of the second regression equations after the initially strongest predictor had been removed.

Type of Science

First-Level

The multiple regression results for the total Sample Two showed unified science to be a significant ($p < .001$) predictor variable accounting for 3.22 percent of the variance. The Science (Unified) course at Rex Putnam High School and Integrated Science course at Milwaukie High School were both included in the unified science variable for Sample Two data. This was the only significant first-level science course with a positive regression coefficient found in any of the initial regression equations.

While unified science was not a significant ($p \leq .05$) predictor variable with the tenth-grade Sample Two students, it did account for 4.92 percent of the SPCT variance. It should be kept in mind that all of the tenth-grade students in Sample Two were from Milwaukie High School.

Earth and space science was a significant ($p < .001$) predictor variable with the 11th-grade students in Sample Two and had a negative regression coefficient. Earth and space science, which is only taught at Milwaukie High School, accounted for 2.92 percent of the SPCT variance for the 11th-grade students.

No first-level science course was a significant predictor variable in the analysis of the total Sample One data. This suggests the possibility that the unified science instruction at the required level either fostered greater retention of science process skill knowledge or provided more useful advance organizers than any of the other types of first-level science.

SPCT

The mean SPCT score for all Sample Two students was 12.11, with a maximum possible score of 24. The mean SPCT scores increased with grade level, as evidenced by means of 11.40 for the 10th grade, 11.85 for the 11th grade, and 12.61 for the 12th grade. The SPCT Subtest with the highest total Sample Two mean was Interpreting Data (2.61). The Subtest with the lowest Sample Two student mean was Modeling (0.92). These Subtest scores are consistent with the Sample One findings.

Sex

Sex was a significant ($p < .001$) variable in accounting for SPCT variance for the total Sample Two data and for Rex Putnam High School students. Sex was an especially strong predictor variable for Rex Putnam High School students, accounting for 6.67 percent of the variance. In both cases, males had significantly higher scores than females. These findings are consistent with those from the analysis of the Sample One data, even though the sex variable was found to be a significant variable less frequently with Sample Two students.

Age

Age was not a significant ($p \leq .05$) predictor variable accounting for two or more percent of the variance in any of the Sample Two regression analyses. This finding was the same as that with the Sample One data.

School

The ANCOVA of SPCT scores by school found that Rex Putnam High School students had significantly higher scores than Clackamas ($p=.004$) and Milwaukie ($p < .001$) High School students. The findings indicate that the science program composed of a first-level Unified Science course and elective courses at Rex Putnam High School developed higher levels of science process skill knowledge as measured by the SPCT than did the science programs at Clackamas and Milwaukie High Schools.

Retention

No significant ($p \leq .05$) differences were found between either the unadjusted or adjusted SPCT scores of students at different grade levels who had elected no science after their required year. This indicates that there was a high level of retention of science process skill knowledge through the high school years.

Elective science

Multiple regression analyses found that the variable "elected science after the required year" was significant ($p < .001$) in accounting for SPCT variance for the total Sample Two scores and for 11th-grade students. Having "elected science after the required year" accounted for 1.59 percent of the variance for the total sample and 4.82 percent of the variance for the 11th-grade students. The scores of students who had elected science were significantly higher than the scores of those students who had not elected science.

An ANCOVA found a significant ($p=.011$) difference between the total Sample Two adjusted mean scores of students who had elected science and those who had not elected science after the required year. The students who had elected science had significantly higher SPCT scores than did those students who had not elected science after the required year.

No statistically significant ($p \leq .05$) differences were found between the adjusted mean scores of students who had elected science and those who had not elected science within each grade level included in Sample Two.

Amount of elective science

At Clackamas High School, having elected two semesters of science after the required year was a significant ($p < .005$) variable accounting for 6.67 percent of the variance. At Milwaukie High School, having elected six semesters of science was a significant ($p < .01$) variable accounting for 3.01 percent of the variance.

No significant ($p \leq .05$) differences were found between either the unadjusted or adjusted SPCT scores of Sample Two students at different grade levels who had elected one or more semesters of science.

Courses

Physics was a significant ($p < .005$) predictor variable for the 11th-grade students in Sample Two and accounted for 2.51 percent of the SPCT variance. Chemistry was a significant ($p < .001$) predictor variable for Rex Putnam High School students in grades 11 and 12. Chemistry at Rex Putnam accounted for 9.41 percent of the SPCT variance. Since biology did not emerge as a significant ($p \leq .05$) predictor variable either as a first-level course (Sample One data) or an elective course (Sample Two date), the findings indicate that the physical science courses were more effective in promoting the development of science process skill competency than were the biological science courses.

Hypothesis Testing

Hypothesis One

Hypothesis one: Academic ability is not a significant variable in accounting for SPCT posttest variance as measured by

a) Reading achievement

b) Language achievement

c) Mathematics achievement

Hypothesis one was rejected. Mathematics achievement (10 cases) and reading achievement (3 cases) were statistically significant ($p < .05$) and the most important predictor variables in all 13 initial regression equations produced from the Sample One and Sample Two data. Mathematics achievement accounted for a low of 41.70 percent and a high of 47.90 percent of the variance in regression equations where it was the most important predictor variable. Reading achievement accounted for 32.98, 42.60, and 52.00 percent of the variance in the regression equations where it was the most important predictor variable.

Language achievement entered one initial regression equation as a predictor variable significant at $p < .05$. Language achievement significantly entered six of the regression equations that were generated after removal of the strongest predictor variable from the initial equation.

Hypothesis Two

Hypothesis two: Sex is not a significant variable in accounting for SPCT posttest variance.

Hypothesis two was rejected. Sex was a significant ($p < .05$) predictor variable in three of the six initial regression equations for Sample One data. Sex was a significant ($p < .05$) predictor variable in two of the seven initial regression equations generated from Sample Two data. In all cases, males had significantly higher scores than females. The findings indicate that within the population investigated sex was a more important predictor variable for grade nine than for any of the other high school grade levels. The findings also indicated that it was a more important predictor variable for Rex Putnam High School students than for students at the other two high schools.

Hypothesis Three

Hypothesis three: Type of science is not a significant variable in accounting for SPCT posttest variance.

Hypothesis three was rejected. Students in all types of science achieved statistically significant gains ($p \leq .05$) between the SPCT pretest and posttest. Rex Putnam unified science students were the only Sample One students to achieve significant gains on all six of the SPCT Subtests. Effect size means from Sample One data showed considerable variation. The mean effect sizes for the different types of science were 0.86 (physical science), 0.44 (biology), 0.37 (earth and space), 0.27 (integrated), and 0.71 (unified). In the second regression equation for Milwaukie High School, Integrated Science entered as a significant ($p < .001$) predictor variable with a negative regression coefficient. For the total Sample Two student scores, unified science was a significant ($p < .001$) predictor variable. Earth and space science was in the initial 11th-grade regression equation with a significant ($p < .001$) and negative regression coefficient.

Hypothesis Four

Hypothesis four: There is no significant difference between the adjusted SPCT posttest means of ninth-grade and tenth-grade students.

Hypothesis four was rejected. An analysis of covariance of SPCT posttest scores by grade level with the SPCT pretest, mathematics achievement, reading achievement, sex, and age as covariates found significant ($p < .001$) differences. Tenth-grade students had significantly higher scores.

Hypothesis Five

Hypothesis Five: There is no significant difference between the adjusted SPCT posttest means of students who have elected no science after the required year and are one, two, or three years removed from required science.

Hypothesis five was not rejected. Analysis of covariance of the SPCT scores of Sample Two students who had elected no science by grade level with mathematics achievement, reading achievement, language achievement, sex, and age as covariates found no significant differences at $p \leq .05$. The ANCOVA procedure was conducted for each school (tables 66, 67, and 68) and for the pooled Sample Two data (table 65).

Hypothesis Six

Hypothesis six: There is no significant difference between the adjusted SPCT posttest means of those students who have elected science after the required year and are one, two, or three years removed from required science.

Hypothesis six was not rejected. Analysis of covariance of the SPCT scores of Sample Two students who had elected science by grade level with mathematics achievement, reading achievement, language achievement, sex, and age as covariates found no significant differences at $p \leq .05$. The ANCOVA procedure was conducted by school (tables 70, 71, and 72) and with pooled Sample Two data (table 69).

For the pooled Sample Two data, the SPCT unadjusted means did increase with grade level, but the differences were not significant at $p \leq .05$.

Hypothesis Seven

Hypothesis seven: There is no significant difference between the adjusted SPCT posttest means of students who have elected science after the required year and students who have not elected science after the required year.

Hypothesis seven was rejected. Analysis of covariance of the pooled SPCT scores of Scample Two students electing science and those not electing science with mathematics achievement, reading achievement, language achievement, sex, and age as covariates indicated a significant difference at $p = .011$ (table 73) favoring those students who had elected science. The ANCOVA by schools did not indicate significant differences between students electing science and those not electing science at $p \leq .05$ (tables 74, 75, and 76). However, in all schools both the unadjusted and adjusted SPCT means of the students who had elected science were higher than the comparable means of those students who had not elected science. In all schools, the unadjusted means of the students who had elected science were significantly ($p \leq .002$) higher than those of students who had not elected science.

Hypothesis Eight

Hypothesis eight: There is no significant difference between the adjusted SPCT posttest means of students who elected science after the required year and students in the same grade level who did not elect science after the required year.

Hypothesis eight was not rejected. Analysis of covariance of the Sample Two grade level SPCT scores of students electing science and those not electing science with mathematics achievement, reading achievement, language achievement, sex, and age as covariates did not indicate any significant differences at $p \leq .05$ (tables 77, 78, and 79).

At each grade level, both the unadjusted and adjusted mean scores of the students who had elected science exceeded the comparable mean scores of those students who had not elected science.

The unadjusted means of the 11th- and 12th-grade students who had elected science were significantly ($p < .001$) higher than the unadjusted means of those students who had not elected science.

Hypothesis Nine

Hypothesis nine: There is no significant difference between the SPCT pretest/posttest effect size for the different types of science.

Hypothesis nine was rejected. A chi-square test of the significance of the deviation of the effect sizes (page 117) from the population effect size mean found significant differences at the 0.05 level. The physical science (tenth-grade students) effect size was significantly higher than the mean of all effect sizes, and the integrated science (ninth-grade students) effect size was significantly lower than the mean of all effect sizes.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The Study

The purpose of this study was to investigate the effects of type of classroom science, grade level where science was required, years without formal science instruction, and elective science courses on the knowledge of selected science process skills of high school students. In addition, the study was designed to identify other program and learner variables important in accounting for variance on a test measuring the level of science process skill knowledge.

The population studied was the 3,777 students enrolled in the three comprehensive high schools of the North Clackamas School District in Milwaukie, Oregon. Two samples were used for data gathering purposes. Sample One was composed of 690 students in the ninth and tenth grades who were enrolled in their first year of high school science that would satisfy their graduation requirement. Sample Two was composed of a total of 210 students randomly selected in groups of 30 from each grade level in each high school following the grade level where science was required.

Science process skill knowledge in the areas of Classifying, Observing, Interpreting Data, Identifying Variables, Modeling, and Measuring was assessed by the administration of an investigator-developed Science Process Competency Test (SPCT). The 24-item, multiple-choice SPCT contained six Subtests, one for each of the science process skill areas being assessed.

The academic achievement level of students in both samples in the areas of reading, language, and mathematics was determined by the use of scores from school district-administered California Achievement Tests (CAT). Additional student information was collected by investigator perusal of student cumulative records and from several questionnaires completed by students. Teacher information was obtained by means of two questionnaires completed by teachers.

The data were gathered during the 1981-82 school year. Sample One students were pretested in September and posttested in May with the SPCT; student questionnaires were completed concurrently with the pretesting and posttesting. Data were gathered from Sample Two students through May posttesting and concurrent questionnaire completion.

The data were analyzed primarily by the use of programs contained within the Statistical Package for the Social Sciences (SPSS). Data were subjected to treatment and analysis by means of correlation, multiple regression, paired t-test, analysis of variance, and analysis of covariance. Effect size computations were also used to assess the educational significance of the SPCT pretest/posttest gains in the various groups contained within Sample One.

Findings

Hypotheses

A detailed discussion of the testing of hypotheses is found on pages 236-242. Nine null hypotheses were tested, each of which is stated in this subsection along with brief comments summarizing the results of the testing.

Hypothesis One: Academic ability is not a significant variable in accounting for SPCT posttest variance as measured by (a) reading achievement, (b) language achievement, and (c) mathematics achievement.

Hypothesis one was rejected. The multiple regression results on pages 122, 126, 130, 138, 142, 147, 171, 175, 179, 183, 189, 192, and 196 show that mathematics achievement (12 times), reading achievement (7 times), and language achievement (1 time) were significant ($p < .01$) variables in accounting for SPCT posttest variance.

Hypothesis Two: Sex is not a significant variable in accounting for SPCT posttest variance.

Hypothesis two was rejected. The multiple regression results on pages 126, 142, 147, 171, and 196 show that sex was a significant ($p < .001$) variable in accounting for SPCT posttest variance. In all cases, the sex variable favored male students.

Hypothesis Three: Type of science is not a significant variable in accounting for SPCT posttest variance.

Hypothesis three was rejected. The multiple regression results found on page 171 show that for the total Sample Two student data, Unified/Integrated Science was a significant ($p < .001$) and positive variable in accounting for SPCT posttest variance. Earth and Space Science, as shown in the multiple regression results on page 179, was a significant ($p < .001$) and negative variable in accounting for the SPCT posttest variance of Sample Two 11th-grade students.

Hypothesis Four: There is no significant difference between the adjusted SPCT posttest means of ninth-grade and tenth-grade students.

Hypothesis four was rejected. The analysis of covariance results on page 155 show a significant ($p < .001$) difference between the adjusted SPCT scores of ninth-grade and tenth-grade students. The tenth-grade students had significantly higher scores.

Hypothesis Five: There is no significant difference between the adjusted SPCT posttest means of students who have elected no science after the required year and are one, two, or three years removed from required science.

Hypothesis five was not rejected. The results of the analyses of covariance on pages 207 through 210 show no significant ($p \leq .05$) differences between the scores of students who had elected no science and were one, two, or three years removed from required science.

Hypothesis Six: There is no significant difference between the adjusted SPCT posttest means of those students who have elected science after the required year and are one, two, or three years removed from required science.

Hypothesis six was not rejected. The results of the analyses of covariance on pages 214 through 217 show no significant ($p \leq .05$) differences between the scores of students who had elected science after the required year and were one, two, or three years removed from required science.

Hypothesis Seven: There is no significant difference between the adjusted SPCT posttest means of students who have elected science after the required year and students who have not elected science after the required year.

Hypothesis seven was rejected. The results of the analysis of covariance of the pooled Sample Two student data on page 221 show a significant ($p=.011$) difference between the scores of those students who had and had not elected science after the required year. The students who had elected science had significantly higher scores.

Hypothesis Eight: There is no significant difference between the adjusted SPCT posttest means of students who elected science after the required year and students in the same grade level who did not elect science after the required year.

Hypothesis eight was not rejected. The results of the analyses of covariance on pages 226, 227, and 229 show no significant ($p \leq .05$) differences between the scores of students at the same grade level who had elected and not elected science after the required year.

Hypothesis Nine; There is no significant difference between the SPCT pretest/posttest effect size for the different types of science.

Hypothesis nine was rejected. The effect sizes on page 117 were tested for significant ($p < .05$) deviation from the population effect size mean by application of a chi-square test. Two effect sizes were found to differ significantly. The Clackamas tenth-grade Physical Science group was significantly higher than the mean, and the Milwaukie ninth-grade Integrated Science group was significantly lower than the mean.

Program Variables

School science program variables that were investigated were type of science, grade level where science was required, and the elective science courses.

Type of science

Pretest/posttest gains

Sample One students in all types of first-level science used in the three high schools had significant ($p \leq .05$) gains from the SPCT pretest to the SPCT posttest (pages 108-115). The mean absolute gain on the 24-point SPCT for all Sample One students was 2.02. The largest absolute gains, 2.65 and 3.24, were made by the ninth-grade and tenth-grade Physical Science students, respectively, at Clackamas High School. The smallest absolute gain was 1.09 by Integrated Science students at Milwaukie High School. Descriptive statistics are on page 105.

Pretest/posttest Subtest gains

The average number of SPCT Subtests where significant ($p \leq .05$) gains were made by the eight groups in Sample One was 4.13 (six subtests). The only type of science where students made significant gains on all six Subtests was Unified Science at Rex Putnam High School. The type of science with the fewest significant gains, one, was Integrated Science at Milwaukie High School. The paired t-tests for the Subtests are on pages 108-115.

Effect sizes

Five of the groups in Sample One showed effect sizes (page 117) that would be considered larger than average and comparatively large when compared to those reported in the literature. The four largest effect sizes were found in two types of science. The Clackamas ninth-grade and tenth-grade Physical Science groups had effect sizes of 0.82 and 0.90, respectively; the Rex Putnam ninth-grade and tenth-grade Unified Science groups had effect sizes of 0.68 and 0.74, respectively. The other effect size considered above average was the 0.51 of the Clackamas tenth-grade Biology group.

Accounting for SPCT posttest variance

Multiple regression analysis (pages 171 and 179) showed Unified/Integrated Science to be a significant ($p < .001$) and positive variable in accounting for *Sample Two* SPCT posttest variance and

Earth and Space Science to be a significant ($p < .001$) and negative variable in accounting for SPCT posttest variance of Sample Two 11th-grade students.

Grade Level Where Science Required

The SPCT pretest means for Sample One students who were entering high school science for the first time were 9.76 for tenth-grade students and 9.44 for ninth-grade students. The unadjusted SPCT posttest means for these same students were 12.06 for the tenth-grade students and 11.18 for ninth-grade students. Descriptive statistics are on page 105.

Analysis of covariance of SPCT posttest scores by grade level with mathematics achievement, SPCT pretest, reading achievement, age, and sex as covariates indicated significant ($p < .001$) differences between the adjusted SPCT posttest scores of the ninth-grade and tenth-grade students (page 155). Tenth-grade students had significantly higher scores. This is consistent with the findings of Pettus and Haley (1980), who reported mean scores on the Test of Science Processes (TOSP) increasing with grade level, but contrary to the other findings reported in the literature.

Elective Science

All data relative to the effect of elective science courses on process skill knowledge were Sample Two data. Unadjusted and adjusted SPCT scores of students who had elected science were in all cases (comparisons by grade level, school, and pooled data) higher than the comparable scores of students who had not elected science. These comparisons can be found on pages 221, 222, 223, 224, 226, 227, and 229. While the analysis of covariance found no significant ($p < .05$) differences between the adjusted posttest scores of the students who had and had not elected science within schools (pages 222 through 224) or grade levels (pages 226, 227, and 229 a significant ($p = .011$) difference was found when the Sample Two data were pooled (page 221). The students who had elected science had significantly higher scores. This finding is consistent with one reported by Pettus and Haley (1980), who found mean scores on the TOSP increasing with the number of science courses taken.

It is possible that an SPCT instrument "ceiling effect" limited the scores for some of the Rex Putnam High School students who had elected science. This possibility is indicated by the relatively high unadjusted mean of 15.70 for these students. It is therefore possible that significant differences existed within Rex Putnam High School that were masked by instrument limitations.

The results of the multiple regression analyses of Sample Two data showed "elective science" as a significant ($p < .001$) and positive variable in accounting for SPCT posttest variance for the pooled Sample Two data (page 171) and for 11th-grade students (page 179). Two semesters of elective science was a significant ($p < .005$) variable in accounting for the SPCT posttest variance at Clackamas High School (page 189) and six semesters of elective science a significant ($p < .01$) variable in accounting for SPCT posttest variance at Milwaukie High School (page 192). The only specific elective science courses to emerge as significant variables in accounting for SPCT posttest variance were Physics ($p < .005$) for the 11th-grade (page 179) and Chemistry ($p < .001$) at Rex Putnam High School (page 196).

Student Variables

Academic Achievement

Sample One

For Sample One data, mathematics achievement was the significant variable ($p < .001$) accounting for the most posttest variance in all multiple regression equations. Multiple regression analyses were conducted by school (pages 138, 142, and 147), grade level (pages 126 and 130), and for pooled data (page 122). Reading achievement was also a significant ($p < .001$) variable for tenth-grade students (page 130) and Rex Putnam High School students (page 147). Language achievement was a significant ($p < .001$) variable in accounting for the posttest variance of Milwaukie High School students (page 142).

Sample Two

For Sample Two students, mathematics achievement was the significant ($p \leq .005$) variable accounting for the most posttest variance in four of the initial regression equations (pages 171, 175, 183, and 192), and reading achievement was the significant ($p < .001$) variable accounting for the most posttest variance in the other three initial regression equations (pages 179, 189, and 196).

Both reading achievement (pages 171 and 183) and mathematics achievement (pages 189 and 196) entered regression equations as significant ($p \leq .01$) variables in situations where they were not the most important variable in accounting for SPCT posttest variance.

Sample One and Sample Two

Mathematics achievement was the most important variable in accounting for SPCT posttest variance in ten initial multiple regression analyses. The average percentage of the variance accounted for by mathematics achievement was 40.87 percent. Reading achievement was the most important variable in the other three cases. The average percentage of the SPCT posttest variance accounted for by reading achievement was 42.53 percent. Reading achievement was a significant variable in accounting for posttest variance in four other cases, while mathematics achievement was a significant variable in accounting for posttest variance in two other regression analyses. Language achievement was a significant variable in one case only.

These findings are consistent with those reported in the literature, but represent somewhat higher positive correlations and percentage of the variance accounted for.

Entry Level Science Process Skill Knowledge

The mean science process skill knowledge level, as measured by the SPCT, of students who were entering their first year of high school science was 9.59. The mean SPCT score for ninth-grade students was 9.44, while the mean SPCT score for tenth-grade students was 9.76. The ninth-grade mean for comparison purposes is somewhat artificially elevated, while the tenth-grade mean is similarly depressed. This is because 35 percent of the ninth-grade students, those from Clackamas and Rex Putnam High Schools, are "selected" high achieving students who are taking their required science a year earlier than their peers. These select students had an SPCT pretest mean of 11.09, compared to an SPCT pretest mean of 8.54 for the remainder of the ninth-grade students, which included the highest achieving ninth-grade students from Milwaukie High School. The tenth-grade students taking their first year of high school science did not have the scores of approximately 120 high-achieving tenth-graders included, because they had completed their required science a year earlier.

SPCT pretest score was the second most important variable in accounting for SPCT posttest variance of Sample One students in all six multiple regression analyses (pages 122, 126, 130, 138, 142, and 147). SPCT pretest score was always a significant ($p < .001$) variable and accounted for an average of 7.91 percent of the variance.

Age

Age was not found to be a significant ($p < .05$) predictor variable accounting for two percent or more of the SPCT variance in either Sample One or Sample Two. This finding is in general agreement with those reported in the literature, where only one study reported a difference within the high school years.

Sex

Sample One

Sex was a significant ($p < .001$) variable in accounting for SPCT posttest variance for Sample One ninth-grade students (page 126), Milwaukie High School students (page 142), and Rex Putnam High School students (page 147). In all cases, males had significantly higher scores than females.

Sample Two

Sex was a significant ($p < .001$) variable in accounting for SPCT variance of the Sample Two pooled data (page 171) and the Rex Putnam High School data (page 196). In all cases, males had significantly higher scores than females.

Sample One and Sample Two

Sex was a consistent significant variable in accounting for SPCT posttest variance of Rex Putnam High School students. In addition, it was a significant variable in three other cases--Sample One ninth-grade students, Sample One Milwaukie High School students, and pooled data for Sample Two students. In all five cases, males had significantly higher scores than females. The sex variable accounted for an average of 2.68 percent of the variance.

This finding is in general agreement with those reported in the literature, especially with the meta-analysis findings of Kahl, Fleming, and Malone (1982).

Conclusions and Recommendations

The reader is reminded that the conclusions that follow were based upon data gathered in the high schools of the North Clackamas School District, and even though the findings from this study are for the most part consistent with the findings reported in the literature, the conclusions and recommendations contained in this subsection are not proposed as being applicable outside the population studied.

Conclusions

1. The most important variable in accounting for the science process skill knowledge as measured by the SPCT was level of academic achievement. This was true at all grade levels and in all schools. The most powerful specific predictor variable was mathematics achievement, followed closely by reading achievement. This is in agreement with the findings reported in the literature.

2. Tenth-grade students as a group had significantly higher levels of science process skill knowledge as measured by the SPCT at the end of the required year of science than did ninth-grade students as a group. This is contrary to the findings reported in the literature. Ninth-grade students with high levels of academic achievement, however, left the year of required science with levels of science process skill knowledge comparable or superior to tenth-grade students.

3. The completion of one or more additional years of high school science instruction after the required year significantly increased the level of science process skill knowledge as measured by the SPCT. This is in agreement with the findings reported in the literature.

4. There was no significant loss of science process skill knowledge as measured by the SPCT during the high school years following the year in which required science was completed. No comparable research findings were located in the literature.

5. There was no significant gain in science process skill knowledge as measured by the SPCT as a result of having completed two or three years of elective science courses. There were an insufficient number of reported findings in the literature to establish a pattern.

6. Physical science elective courses (e.g., chemistry, physics) were more effective in increasing science process skill knowledge as measured by the SPCT than were biological science courses. The literature contained an insufficient number of comparative research findings to establish a pattern.

7. Students who did not elect any science after the required year left high school with relatively low levels of science process skill knowledge as measured by the SPCT. This was true in all three schools. While no measurements were made in the process skill competency areas of Experimenting and Communicating, it is reasonable to infer that these areas were also relatively low because of their subsuming relationship to the more basic science process skills assessed.

8. The science process skill competency concerned with students being able to recognize and use scientific models was not being effectively addressed by existing first-level science courses.

9. The Physical Science course at Clackamas High School and the Unified Science course at Rex Putnam High School more effectively addressed the science process skill competencies than did the other first-level science courses in the school district.

10. The amount of variation in science process skill knowledge as measured by the SPCT that could be accounted for on the basis of sex was small (e.g., two to three percent) and consistently favored males. This is in general agreement with findings reported in the literature, and especially consistent with the meta-analysis findings.

11. Age, when treated separately from grade level, was not a significant variable accounting for two percent or more of the SPCT variance in either Sample One or Sample Two. This is in agreement with high school level findings reported in the literature.

12. The science program (Unified Science course plus elective science courses) at Rex Putnam High School produced students with significantly higher levels of science process skill knowledge as measured by the SPCT than did the programs at the other high schools.

13. The required science programs at Rex Putnam High School and Clackamas High School produced students with significantly higher levels of science process skill knowledge as measured by the SPCT than did the required science program at Milwaukie High School.

14. The declared teacher emphasis on the science process skills showed a strong relationship to student performance on the SPCT. This is in general agreement with the findings reported in the literature.

Recommendations

1. Since the most important student variable associated with science process skill knowledge was the level of academic achievement, it is recommended that the school district continue to increase its emphasis on basic skill development at all grade levels. In addition, it is recommended that science instruction in the high schools be designed to concurrently emphasize and strengthen basic skill development in students, especially in the areas of mathematics and reading. Appropriate inservice education activity should be undertaken to facilitate the implementation of this recommendation.

2. Since tenth-grade students as a group achieved higher levels of science process skill knowledge than did ninth-grade students during the required year of science, it is recommended that the required year of science be designated at grade ten in all buildings. It is also recommended that provisions be made for ninth-grade students with high levels of academic achievement to complete their required science during grade nine. This would provide them with the maximum opportunity to take advantage of the elective science program within each building.

3. Since the completion of one or more years of high school science after the required year resulted in significantly higher

levels of science process skill knowledge and students who have left school with only one year of science had relatively low levels of science process skill knowledge, it is recommended that two years of science be required during high school.

4. It is recommended that inservice training in the science process skills be implemented for all high school science teachers. The inservice design should include provisions for instruction directed towards increasing the level of teacher understanding of the science process skills, instructional strategies appropriate for teaching the various science process skills, and evaluation techniques for assessing the level of science process skill knowledge of students. The science process skill with the highest priority within the inservice structure should be Modeling.

5. Since the Milwaukie High School required science program was significantly less effective than the programs in the other two schools in terms of student posttest levels of science process skill knowledge, it is recommended that the program be closely examined in terms of year that science is required, emphasis on the science process skills, and instructional strategies used for teaching the science process skills and changes implemented to improve the level of science process skill knowledge being attained by students. It is further recommended that the SPCT be used as one of the criteria for judging the effectiveness of any changes that are made in the program.

6. In order to facilitate the design and implementation of instruction and the evaluation of learning outcomes in the science process skills, it is recommended that the district adopt definitions for the science process skills included in the minimum competencies and revise the science process skill competency statements in order to:

a) Avoid including two or more different process skill competencies (e.g., make laboratory observations and make inferences from these observations) within a single competency statement

b) Avoid competency statements that specify one learner action (e.g., fit an object into a scientific classification scheme) and accompanying sample performance indicators that specify another action (e.g., devise a classification scheme)

c) Include sample performance indicators in a general science context as well as in the context of each of the types of science being used at the required science level

7. It is recommended that the district continue to use the SPCT as a measure of science process skill knowledge and strive to improve the district's science program until the mean for students completing their required year(s) of science in each building and the district as a whole reaches a minimum of 12.00.

8. It is recommended that the school district consider the use of this study as a model for evaluation of the level of student achievement and instructional programs in the high school level minimum competencies in other areas of the curriculum.

SPCT Instrument

The SPCT may be worthy of further development, based upon its relative freedom from questions cast in a single science context, range of appropriate grade levels, apparent external validity, and acceptable level of reliability.

The following represent potential activities in the further development and/or use of the SPCT instrument.

1. Increased use of the instrument, especially outside of the North Clackamas School District, in order to establish norms.

2. Expansion of the instrument to include Subtests measuring science process skill knowledge in the approximately 15 science process skills generally acknowledged as appropriate learning outcomes for high school science programs.

3. Item and factor analysis procedures with appropriate revision in order to strengthen the ability of Subtests to effectively measure the level of knowledge in the science process skills,

4. A study to determine the correlation between student scores on the SPCT and its Subtests and student performance of the same skills in the laboratory setting.

5. Investigation of a possible "ceiling effect" for more able students.

6. Investigation of possible reading level limitations for less able learners.

Desirable Studies

The review of the literature produced a rather surprising dichotomy relative to science process skill learning outcomes at the high school level. It was apparent that science process skill learning outcomes are being promoted as highly valued, but it was also apparent that there is a paucity of published research relative to the teaching and learning of science process skills at the high school level. There is, therefore, a high priority need for research directed toward providing greater understanding of the teaching and learning of science process skills in high school science. The need is especially great in the area of instructional strategies and during the required year(s) of science.

The importance of type of science in the teaching and learning of science process skills is still very much an open question. Variation in emphasis on the science process skills, science process skill knowledge of teachers, instructional strategies, use of the laboratory, and a number of other teacher-related variables combine with student differences in academic ability, beginning level of science process skill knowledge, stage of cognitive development, and other variables to require carefully controlled experimental studies, which at this time appear to be extremely limited.

The effects of teacher inservice on student learning outcomes in the science process skills is an area of major importance to school districts desiring to improve the science process skill knowledge of their students. This would be an especially appropriate study in the

North Clackamas School District, where baseline data for student science process skill knowledge without teacher inservice training are now available.

The retention of science process skill knowledge by students is a basically unexplored question at the high school level. The findings of this study appear to be the only results available at this time. Another question of interest is the usefulness of the science process skills, especially outside of formal science instruction.

Much needs to be done in better understanding the nature of the individual science process skills in relation to the readiness and limitations of the high school age learner, as well as strategies appropriate for teaching the skills. A fundamental question worthy of investigation is the comparative effectiveness of science process skill instructional units and science process skill instruction by means of infusion. Much of the knowledge that currently is available in these areas is reported under the general heading of developmental psychology, learning theory, or related titles. Consolidating and expanding the existing knowledge and then reporting it in relation to the science process skills or individual science process skills would be a most useful and welcome endeavor in the science education community.

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APPENDIX A

NORTH CLACKAMAS SCHOOL DISTRICT INFORMATION

1. Overview of the North Clackamas School District
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OVERVIEW OF THE NORTH CLACKAMAS SCHOOL DISTRICT

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General Information

The North Clackamas School District was formed by reorganizing four elementary school districts and a union high school district in 1971-72. Geographically, the nearly rectangular school district occupies approximately forty-two square miles to the immediate south and east of Portland, which is Oregon's largest city. The district encompasses rural, urban, residential, manufacturing, forest, and agricultural land. The school district estimates a population of 100,000 and 33,000 residences within its boundaries (Browne 1982). There are three incorporated cities within the school district. As of 1 July 1981 the populations of these cities were estimated to be 17,930 for Milwaukie, 1,480 for Happy Valley, and 360 for Johnson City (Center for Population Research and Census 1981).

The major employers located within the school district, listed in descending order, are the North Clackamas School District, Omark Industries (saw chain), Precision Castparts (steel castparts), Ford Industries (automatic telephone answering systems), and the Kaiser Foundation Hospitals. Each of these employs 500 or more personnel (Research and Agency Liason Division 1979-80 and North Clackamas County Chamber of Commerce 1980). However, the majority of the working adults who reside within the school district are employed outside of the district (Browne 1982).

Educational Facilities

The educational facilities of the school district consist of nineteen elementary schools, four junior high schools, three high schools, and an occupational skills center, where students from the three high schools and a nearby private school can elect to spend a portion of their school day for specialized vocational training and career education experience. The junior high schools include grades seven and eight only. The high school attendance areas are such that each of the high schools receives entering ninth-grade students from several of the junior high schools.

Student Population

The 1981 fall enrollment of 12,514 kindergarten through grade twelve students ranked the North Clackamas School District as the fifth largest in Oregon. School district projections indicate gradual growth in the student population over the next decade. It is anticipated that the total enrollment will increase by approximately fifteen percent by the 1990-91 school year. With this anticipated growth, the total student population will then exceed the previous peak of 14,079, which was reached during the 1973-74 school year (Browne 1982).

While the vast majority of the students attending schools within the district reside in a suburban setting, there are approximately 125 high school students from a rural environment. These students, who live beyond the designated urban growth boundary, attend Clackamas High School. The school district has a very low minority enrollment, with approximately one percent minority students. The composition of this minority enrollment is approximately sixty-nine percent Asian, twenty-three percent Hispanic, and eight percent black (Browne 1982). Information gathered by the three high school Guidance Departments provides some insight into the postgraduation history of North Clackamas students. The majority of the graduates pursue some further form of continuing education, with forty-nine percent attending colleges and universities, predominantly within the state. Another four percent become involved in technical/vocational training. Thirty-seven percent enter the work force immediately following graduation. Military service, homemaking, and other categories comprise a total of only ten percent.

SCIENCE PROGRAM GOAL, MINIMUM GRADUATION COMPETENCIES, AND SAMPLE PERFORMANCE INDICATORS

SCIENTIFIC/TECHNOLOGICAL PROCESSES

1.7.1 GOAL: The student will utilize scientific processes.

Competencies	SAMPLE Performance Indicators
1.7.1.1 The student is able to fit an organism, object or substance into a scientific classification scheme.	1.7.1.1.1 Given common objects, the student will devise a classification system that effectively distinguishes the objects.
1.7.1.2 The student is able to make laboratory observations and make inferences from these observations.	1.7.1.2.1 Given statements relating to a written paragraph, the student will determine which are inferences and which are observations.
1.7.1.3 The student is able to communicate scientific concepts and ideas with the teacher and fellow students.	1.7.1.3.1 Given a set of data, the student will construct a simple graph to summarize that data. 1.7.1.3.2 Given a list of vocabulary words, the student will correctly define 80%.
1.7.1.4 The student is able to interpret data and make predictions from these interpretations.	1.7.1.4.1 Given experimental data, the student shall be able to interpolate and extrapolate.
1.7.1.5 The student is able to recognize variables and predict what would happen when selected variables are altered.	1.7.1.5.1 Given an experiment, the student will list the variables.
1.7.1.6 The student is able to set up and complete an experiment.	1.7.1.6.1 Given a laboratory situation, the student will set up an experiment.
1.7.1.7 The student is able to recognize and use scientific models.	1.7.1.7.1 Given a series of events, the student will devise or recognize a device or structure that will enable the event to be tested or explained.
1.7.1.8 The student is able to demonstrate a knowledge of the metric and use common measuring instruments.	1.7.1.8.1 Given an object in the lab, the student will appropriately measure its size and mass in the metric system.

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FIRST-LEVEL HIGH SCHOOL SCIENCE COURSES IN THE NORTH CLACKAMAS SCHOOL DISTRICT

FIRST-LEVEL HIGH SCHOOL SCIENCE COURSES IN THE NORTH CLACKAMAS SCHOOL DISTRICT

Overview

In the North Clackamas School District, the individual high schools are granted fundamental autonomy relative to the specifics of the science curriculum. Course offerings, course titles, course goals, basal textbooks, course content, instructional strategy, and evaluative techniques are the result of decisions made within the high school building. There is no district level science supervisor or coordinator.

The district's framework for high school science is its one science program goal and eight corresponding minimum graduation competencies in science. The science program goal for instruction in grades nine through twelve is "The student will utilize scientific processes" (North Clackamas School District 1975). The only other guaranteed common characteristic is that all students are required to earn one unit of laboratory science credit in order to fulfill graduation requirements. The North Clackamas School District does not allow credit by examination.

Each of the high schools operates with a seven period school day and fifty minute class periods. While the buildings vary considerably in age, quality, and level of care, the overall science teaching facilities have been judged as adequate for the courses being taught, and the district is considered to be providing the essential teaching and learning materials for science (School Standardization Section 1978).

Science course credit in each high school is granted and recorded on a semester basis. Numerical designations following descriptive course titles indicate the semesters available and are sequential. Courses not carrying a numerical designation are non-sequential. Students at Clackamas and Milwaukie High Schools are scheduled for science classes on a full-year basis. At Rex Putnam High School, a complete new scheduling process is undertaken prior to each semester. The most significant impact of this scheduling difference is that many Rex Putnam students will not have the same science instructor for the second semester of their first-level science course.

Clackamas High School

The first requirement fulfilling science courses available at Clackamas High School are Biology 1-2 and Physical Science 1-2. These two courses are well established at the school and taught by experienced teachers. The courses would probably be described by most observers as rather typical of their type.

Grade nine students who express an interest in electing science during their first year of high school are asked to make a commitment to complete at least one additional year of science prior to being allowed to enroll. The only science course that can be completed in grade nine is Physical Science 1-2. The majority of the students who are enrolled in Physical Science 1-2 and Biology 1-2 are tenth-grade students who are completing their first year of high school science. There is no ability grouping in either of these courses at Clackamas High School.

Milwaukie High School

At Milwaukie High School, all regular grade nine students are enrolled in science. The options available to them are Biology 1-2, Earth and Space Science 1-2, and Integrated Science 1-2. The Biology 1-2 and Earth and Space Science 1-2 are well established courses taught by experienced teachers. They would probably be considered similar to most high school level courses in those subject-matter areas. One section of each of these classes has been identified as "AA" and reserved for highly motivated students with a particular aptitude for science. In addition, these students must have completed first-year algebra in grade eight or be enrolled in it during grade nine. They must also have a recommendation from their junior high school science teacher in order to enroll. The "AA" sections operate under the same planned course statement and use the same basal texts as other sections.

Integrated Science 1-2 was initiated during the 1980-81 school year by a Milwaukie High School science teacher who had completed his student teaching experience at Rex Putnam High School. It is basically a unified science course relying heavily on the student instructional materials developed by the science staff at Rex Putnam High School. Additional information regarding these materials will be found in the discussion of the first-level science courses at Rex Putnam High School. Integrated Science 1 was taught for the first three weeks of the 1981-82 school year by a substitute teacher. During the remainder of that school year it was taught by a beginning science teacher who had completed her student teaching experience at Rex Putnam High School. Prior to the

Integrated Science 1-2 course being initiated at Milwaukie High School, a physical science course had been the third science option for grade nine students.

Rex Putnam High School

The only first-level science course that will fulfill the graduation requirement at Rex Putnam High School is Science 1-2. It is a competency-based unified science course developed by the Rex Putnam High School science staff over a four year period. The unified science approach consists of assembling instructional units around organizing themes that are appropriate for viewing the scientific enterprise holistically (e.g., major science concepts, science process skills, natural phenomena, science/society type problems), and then incorporating learning activities that are drawn from a number of different science disciplines. Work was initiated on Science 1-2 in 1976. For the prior six years, the first year of the Portland Project Integrated Science Sequence had been the required science course. This course integrated content and learning activities from biology, chemistry, physics, environmental science, and the behavioral sciences.

The Science 1-2 student instructional materials are reproduced by the school district and made available to students in a three-ring binder. The course is now well established and three of the four staff teaching it have had multiple years' experience with the materials. The majority of the students enrolled in Science 1-2 are in grade ten. Students in grade nine wishing to enroll must support their request with a positive recommendation from their grade eight science teacher. There is no ability grouping in Science 1-2.

Owen Sabin Occupational Skills Center

While the Occupational Skills Center does not have a Science Department or offer what typically would be considered high school science classes, several of their vocational clusters offer courses that have some components that are closely related to those in high school science classes. Among these classes are Forest Products 1-2, Agricultural Occupations, Nursery and Landscaping, Electricity/ Electronics 1-4, and Health Occupations 1-2. While students completing these courses may well have developed increased knowledge and competence in some aspects of science, none of the courses fulfill the high school graduation requirement in science.

APPENDIX B

PLANNED COURSE STATEMENTS

1. Clackamas High School Biology
2. Clackamas High School Physical Science
3. Milwaukie High School Biology
4. Milwaukie High School Earth and Space Science 1
5. Milwaukie High School Earth and Space Science 2
6. Rex Putnam High School Science 1 (Unified Science)
7. Rex Putnam High School Science 2 (Unified Science)

CLACKAMAS HIGH SCHOOL BIOLOGY

PLANNED COURSE STATEMENT

TITLE: Biology	AREA: Scientific/Technological Process
CREDIT: 1.0	SCHOOL: CHS

PREREQUISITES: Eighth grade competencies

I. PURPOSE:

To provide the student with a basic understanding of the processes of science, their history, and the uses of scientific methods with emphasis on the variety and relationships in the plant and animal world and the effects of these relationships on man, his society, and his environment.

II. COURSE CONTENT:

1. Metric system
2. Basic chemistry
3. Energy
4. Cells
5. Genetics and evolution
6. Animal taxonomy
7. Development and systems
8. Animal behavior
9. Microbiology
10. Plant taxonomy
11. Gardening
12. Ecology

III. LEARNING ACTIVITIES:

A. Laboratory investigations (qualitative and quantitative observations).
B. Demonstrations of laboratory procedures, techniques, and scientific phenomena.
C. Visual and auditory aids (overhead projections, films and filmstrips, chalkboard, models, charts, records, tapes, opaque projections).
D. Games and simulations.
E. Reading, discussion, and lecture.
F. Laboratory write-ups, quizzes, tests.

IV. ANTICIPATED LEARNER OUTCOMES:

Refer to the listed course goals and performance indicators on the following pages.

V. PROCEDURES FOR EVALUATION:

In order to receive a passing grade the student must accurately complete 55% of the performance indicators representing each Basic Course Goal (District minimum competencies). The D student will only be required to meet this requirement. In order to receive an upper-level grade, a student must meet this requirement and also complete satisfactorily a higher percentage of the performance indicators representing the basic process goals as well

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as performance indicators representing goals other than the district minimums. The following is a breakdown of the percentage requirements for upper-level grades: 100 - 90% = A, 89 - 80% = B, 79 - 70% = C. Activities by which the student will be assessed for completion of a performance indicator will include observation of classroom performance, test questions (multiple choice, matching, fill-in, essay), work sheets and laboratory write-ups, and project and library research write-ups. The student will be required to attend class regularly in order to fulfill the above requirements.

BASIC COURSE GOALS*

The Basic Course Goals listed below are involved with the processes of science which students are required to use during this course. These processes apply in varying degrees to some or all Subject Areas (course content).

1. The student will be able to fit an organism, object or substance into a scientific classification scheme.
2. The student will be able to make observations and inferences from these observations.
3. The student will be able to interpret data and make predictions from those interpretations.
4. The student will be able to communicate scientific concepts and ideas with the teacher and fellow students.
5. The student will be able to recognize a variable and predict what would happen when selected variables are altered.
6. The student will be able to set up an experiment and draw logical conclusions from the data.
7. The student will be able to recognize and use a scientific model.
8. The student will be able to use the metric system and common measuring instruments.

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* District minimum competencies

Subject Area Goal - Cells

Competencies	SAMPLE Performance Indicators	B.C.G. No.
The student will know the basic structure and function of various types of cells.	Given a list of organelles of a cell, the student matches each with a description of its function.	-
	Given a demonstration of osmosis in a cell model, the student identifies movement of materials and infers relationships of concentrations of materials to their movement.	2,7

Subject Area Goal - Genetics and evolution

Competencies	SAMPLE Performance Indicators	B.C.G. No.
The student knows common human characterisitcs that are genetically controlled.	Given a list of human characteristics, the student identifies those that are genetically controlled.	-
	Given a group of individuals, the student determines observable differences among them and infers genetic control of those characteristics.	2
The student knows how the structure of the DNA molecule determines the structure of an organism.	The student writes a short essay explaining the general method by which DNA and RNA work together to replicate proteins.	4,7
The student knows advantages and disadvantages of sexual and asexual reproduction.	Given life histories of representative organisms showing sexual and asexual reproduction, the student will distinguish and explain portions of each type of life cycle which would be of advantage or disadvantage to the organism.	2,3,4
The student will apply Mendel's laws of heredity to solve problems involving genetic crosses.	The student predicts the possible percentages of genotypes and phenotypes in a monohybrid cross.	3
	The student uses a Punnett square to illustrate genetic crosses.	7

	The student designs experiments involving test crosses which will reveal genotypes of parental organisms.	6
The student will separate environmental and genetic factors that influence development.	Given tobacco seeds which should produce a ratio of 3 green to 1 albino, the student will determine experimentally the relative roles of genetics and environment in controlling seedling color.	2,3,5,6
The student knows moral, ethical, and legal issues involved in the possible uses of genetic engineering.	The student writes a short essay explaining advantages and disadvantages of genetic engineering and giving his opinion of the desirability of its use.	4
The student knows factors of the evolutionary process which produce changes within a species.	Given descriptions of specific populations and environmental factors affecting them, the student determines survival abilities and selective pressures, and predicts which populations will become dominant in an area.	2,3
	Given sets of green and white paper discs thrown randomly on a green background, the student explains how this can be used to represent natural selection.	7
The student knows evidence of events in past which contribute to the theory of evolution.	Given the fossil evidence of the organisms of a particular geologic time period, the student reconstructs the ecosystem which then existed.	2,7

Subject Area Goal - Animal Taxonomy

Competencies	SAMPLE Performance Indicators	B.C.G. No.
The student knows characteristics and groupings used to organize members of the animal kingdom.	Given a variety of animals, the student observes their characteristics and uses a dichotomous key to classify them into their proper taxonomic group(s).	1,2

Subject Area Goal - Development and systems

Competencies	SAMPLE Performance Indicators	B.C.G. No.
The student knows structural and functional characteristics of major life process mechanisms and systems from the simplest organisms to the most complex.	Given a microscope and three different one-celled organisms, the student observes and describes obvious life process mechanisms, and makes inferences concerning operation of less obvious mechanisms.	2
	The student will dissect specimens of a squid and a frog and compare the structural differences between them, while hypothesizing possible functional differences of organs.	2
The student knows from an evolutionary standpoint the relationship between function and form for the major organs and organelles in organisms of varying complexity.	The student will trace the development of the circulatory system through the various phyla of animals.	-
	The student writes a short essay giving his opinion on the value to man of an enlarged cerebrum in the brain as compared to the lack of a nervous system in a one-celled organism.	4
The student knows how organisms are adapted to the environment in which they live.	Observing an organism in its natural habitat, the student will describe how the organism appears to be adapted for life in its environment.	2

Subject Area Goals - Animal Behavior

Competencies	SAMPLE Performance Indicators	B.C.G. No.
The student knows the types of behavior shown by animals and how these behavior patterns are acquired.	The student describes how he might test the hypothesis that unhatched chicks detect and remember sounds, using the following equipment: some fertilized chicken eggs, one or two incubators, and a metronome.	6
	The student writes a short essay describing social behavior in bees.	4

Subject Area Goals - Microbiology

Competencies	SAMPLE Performance Indicators	B.C.G. No.
The student knows the structure and function of general groups of microorganisms.	The student uses a drawing as a model to show the basic structure of a virus.	7
	The student will set up an experiment to show fermentation rates in different organism.	6
The student knows and tests factors which affect microbial population growth.	The student looks at a ring of inhibition around a bacterial colony and explains its existence.	2
	Given an inoculated petrie dish, the student uses antibiotic discs to test for the most effective antibiotic against the inocualted bacteria.	2,6
	The student writes a short essay describing how fractional sterilization works.	4
	The student will list the variables in an experiment testing the effects of chemicals on bacteria.	5
The student is able to classify microorganisms from observed, illustrated, or described characteristics or life processes.	Given a description of a microbe, the student classifies it as a virus, fungus, bacteria, or rickettsiae.	1

Subject Area Goal - Plant Taxonomy

Competencies	SAMPLE Performance Indicators	B.C.G. No.
The student knows characteristics and groupings used to organize members of the plant kingdom.	Observing the characteristics of a variety of plants, the student uses a dichotomous key to classify each into its proper taxonomic group(s).	1.2

Subject Area Goal - Gardening

Competencies	SAMPLE Performance Indicators	B.C.G. No.
The student knows basic gardening techniques, garden plants, and methods of satisfying plant requirements.	The student will give an oral report on preparation of soil for vegetable cultivation.	4
	Given an imaginary garden plot the student devises a plan for preparing and planting the area.	-

Subject Area Goal - Ecology

Competencies	SAMPLE Performance Indicators	B.C.G. No.
The student knows characteristics of populations and factors affecting population changes.	The student performs a study of a yeast population and determines how this applies to the characteristics of all population.	6,7
The student knows how energy is transferred through food webs or chains.	Given a description of a food pyramid the student will evaluate and justify the diminishing numbers of organisms at each level of the pyramid.	2
The student knows the various physical and biological interactions in an ecosystem.	Given descriptions of relationships between organisms in a community, the student will identify them as predation, parasitism, commensalism, mutualism, or competition.	1,2
	Observing two different community types, the student describes abiotic factors which affect the type of life which can survive in each community.	2
The student recognizes various forms of pollution and understands their effect on the environment.	The student points out four examples of pollution in Clackamas County and explains how each affects his own life.	2,4
The student knows environmental trade-offs that must be made in solving land use problems.	The student plays land use simulation games.	3,7

The student knows the possible effects of overuse of natural resources on the environment and society.	Given available data, the student predicts when various resources will become exhausted.	3
	Assuming the exhaustion of a resource, the student predicts substitutions and adjustments which will have to be made on environmental and societal levels.	3

Source of reference: Tri-County Course Goals (K - 12)

CLACKAMAS HIGH SCHOOL PHYSICAL SCIENCE

PLANNED COURSE STATMENTS

TITLE: Physical Science Survey
CREDIT: 1.0
PREREQUISITES: none

AREA: Science
SCHOOL: CHS

I. PURPOSE:

a. to teach a scientific approach to problem solving
b. to effectively use the metric system in measuring matter
c. to separate and identify various types of matter by using characteristic properties
d. to gain insight into the atomic model of matter by use of radioactivity, decomposition, and synthesis of substances and molecular motion
e. to become aware of the role of mathematics in qualitative and quantitative analysis

II. COURSE CONTNET:

The course will introduce the student to the measurement, identification, synthesis, and decomposition of matter by experiments, demonstrations, and discussions of matter.

III. LEARNING ACTIVITIES:

a. student experimentation
b. teacher demonstration
c. class discussion
d. film, photographs, and the overhead projector will be used to aid in understanding

IV. ANTICIPATED LEARNER OUTCOMES:

Minimal competency in an outcome will be noted as a "D". As competency improves, the level will be noted as a "C", "B", or "A" with the highest level being an "A".

Competencies

1. To use the metric system to determine the quantity of matter by both direct and indirect measurement.

1. D_1 Given a rectangualr solid, the student will find its mass, length, and width to the nearest .1 unit of measurement.

1. D_2 Given a liquid, the student will determine its mass and volume to the nearest .1 measurement unit.

1. C_1 The student will measure the volume of an irregularly shaped solid such as sand.

1. C The student will calculate the volume of a rectangular solid by multiplication of length, width, and height.

1. B Given the density of a liquid, a student will determine the volume by finding the mass and calculating the volume.

1. A Given an alkaseltzer tablet, the student will dissolve it and determine the mass and volume of gas produced.

2. To write an analysis of an experiment or demonstration

2. D The student will do an experiment that gives data for formulation of a conclusion by using the data found.

2. C The student will determine the objective, collect the data and formulate a conclusion based upon his data and in response to his objective.

3. To be able to separate matter

3. D_1 Given a mixture of solids, the student will separate them by filtration.

3. D_2 Given a mixture of liquids, the student will separate them by fractional distillation.

3. C Given a mixture of soluble solids, the student will separate them by fractional crystallization.

3. B_1 Given a mixture of liquids and solids in solution, the student will separate each from the mixture.

3. B_2 Given black ink, the student will separate it by distillation and chrometography.

4. To be able to identify matter by using characterisitc properties

4. D Given two similar appearing solids, the student will distinguish between them by density.

5. Be able to produce compounds and elements and be able to distinguish between them

5. D Given a quantity of sodium chlorate, the student will decompose and produce oxygen and identify it through testing.

5. C Using electrolysis equipment, the student will produce hydrogen and oxygen and identify them.

5. B Using data from previously done experiments, the student will explain the synthesis of water.

5. A Given zinc and chlorine, the student will produce zinc chloride and identify it as a substance different than the origianal.

6. To be able to show some effects of radioactivity

6. D_1 From a demonstration using a counter source and timer, the student will explain the difference between actual count and background count.

6. C From data collected in demonstration in class, the student will give a simple explanation of the effect of time, distance, and thickness of material on radiation count.

6. B From the data in the above, the student will show the effect mathematically of distance, time, and thickness of a substance on radiation count.

6. A From the above, the student will explain the effect of distance on count by use of the Inverse Square Law.

7. To be able to illustrate the law of constant proportions in compounds

7. C Shown data from an experiment on the synthesis of water, the student will explain the concept that water is two parts hydrogen to one part oxygen by volume.

7. B The student will synthesize zinc chloride and determine the ration of zinc to chlorine and a possible formula.

8. To determine the approximate size of an atom or molecule

8. D Given a known volume of oleic acid, the student will compute the approximate thickness it has when spread on water and relate this to the possible thickness of an atom or molecule.

8. C Using the principle of the above competency, the student will calculate the approximate volume and mass of a oleic acid molecule.

8. B Using data from competencies above, the student will calculate the approximate number of molecules or atoms in a CM^3 of oleic acid.

8. A Using the principles from the above and textbook, the student will explain the process used by scientists to determine the size of polonium and hydrogen atoms.

9. To explain the effect of molecular motion on matter

9. D Given a tube of frozen bromine and air, the student will explain molecular diffusion of the bromine through the air.

9. C Using copper sulfate in a layered solution, the student will explain the upward diffusion of the copper sulfate through the layer of water.

9. B Using a gas model machine, the student will show relationship of density, pressure and volume to molecular motion in a gas.

9. A The student will explain by construction of a graph, Boyle's Law.

10. To explain some properties of matter and heat

10. B_1 The student will determine the calories absorbed in heating two beakers of water, one of 100 ml and the other of 200 ml, 20° C.

10. A_1 The student will determine the specific heat of cooking oil by experimentation.

10. A_2 The student will determine the specific heat of steel washers by experimentarion.

10. A_3 The student will determine the heat of fusion and vaporization by experimentation.

MILWAUKIE HIGH SCHOOL BIOLOGY

PLANNED COURSE STATEMENT

TITLE: Biology 1-2
CREDIT: .50 - .50
PREREQUISITES: None

AREA: Scientific/Technological Processes
SCHOOL: MHS

I. PURPOSE:

The student shall acquire an awareness and an appreciation for the environment.

II. COURSE CONTENT.

- Attitudes and values
- Use and care of laboratory equipment
- Metric system
- Nature of life
  - Basis - chemical and structural
  - The cell - nutrition, metabolism, growth and reproduction
- The continuity of life
  - Hereditary principles
  - Population genetics
  - Applied genetics
  - Evolution
- The diversity of life
  - Microbiology: viruses-rickettsiae-bacteria-infectious diseases-protozoa fungi-algae
  - Multicellular plants: mosses-ferns-seed plants
  - Invertebrates: sponges-coelenterates-worms-parasitic worms-mollusks, echinoderms-arthropods
  - Vertebrates: primitive chordates-fishes-amphibians-reptiles-birds-mammals
  - Classification
  - Human influence on natural systems
  - Careers in the biological sciences

III. LEARNING ACTIVITIES:

- Laboratory experiments and exercises
- Study guides
- Oral discussion
- Lecture
- Student presentation of material
- Bringing in related specimens
- Bringing in related news articles

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Summarizing TV programs
Summarizing Science World articles
Adapting game shows, *e.g.* "bio-gambit"; "bingo" (FOR REINFORCEMENT OF LEARNING ONLY)
Crossword puzzles and word scrambles
Quizzes (oral and written)
Answering questions on the bonus point board

IV. ANTICIPATED LEARNER OUTCOMES:

District competencies are indicated by an asterisk (*).

GOAL 1.0: The student will develop an awareness of the attitudes of science and assess personal values.

Competencies	SAMPLE Performance Indicators
1.1 The student values the ability to make rational and informed judgments, choices, and decisions.	
1.2 The student values scientific knowledge and processes which are needed to validate information about situations.	
1.3 The student knows that different individuals value different things, ideas, and behaviors to satisfy essentially similar basic needs.	
1.4 The student is able to modify or restructure values and behavior in response to increasing knowledge of situations and self.	
1.5 The student values scientific knowledge and processes which aid in identifying basic needs of our society.	
1.6 The student values a society which provides freedom to express and communicate facts, ideas, and opinions.	
1.7 The student values curiosity: about self, reality, the future, causes and effects, alternatives, etc.	
1.8 The student values problem solving.	
1.9 The student values lives of living organisms.	

1.10 The student values the uniqueness or worth of individual lives.	
*1.11 The student values open and accurate communications.	
1.12 The student values the accepting responsibility for the consequences of his/her decisions and actions.	
1.13 The student values creativity and imagination: the pleasure of manipulating and extending ideas.	
1.14 The student values a philosophical, unhostile sense of humor.	
1.15 The student values information which presents challenges to assumption, principles, or values currently considered valid (information which forces us to expand and alter current knowledge toward more accurate and adequate representations of reality).	
1.16 The student values the role of science in meeting society's needs.	
1.17 The student values self.	
*1.18 The student is able to list and discuss the attitudes which underlie scientific discovery and apply these attitudes to laboratory and study situations.	1.18.1 Given a series of specific, structured observations the student will apply those attitudes which relate to each observation, _e.g._ open mind, curiosity, serendipity, intellectual honesty, respecting the opinions of others, making observations for oneself, imagination, etc. 1.18.2 Given lab exercises and study sheets, the student will indicate those attitudes appropriate to the task.

GOAL 2.0: The student is able to use laboratory equipment effectively and safely.

Competencies	SAMPLE Performance Indicators
2.1 The student knows the terms and use of laboratory equipment.	2.1.1 Given the task, the student will identify lab equipment and state its use.

2.2 The student is able to use sense extending equipment effectively and safely (microscope, stereoscope, etc.).	2.2.1 Given the task, the student will prepare a slide and focus it under the microscope.

GOAL 3.0: The student will effectively use the system international (metric).

Competencies	SAMPLE Performance Indicators
*3.1 The student knows the meanings of the term "estimate" (i.e. tentative judgment; approximate determination prior to actual measurement).	3.1.1 Given specific tasks, the student will first estimate the length, mass or volume, then use metric tools to verify the estimations.
*3.2 The student is able to demonstrate a knowledge of the metric system.	3.2.1 Given a list of metric terms, the student will state the English equivalent.
*3.3 The student is able to apply metric measurement to the microscope.	3.3.1 Given the tasks, the student will estimate focused specimens in microns. *3.3.2 Given the pooled data from a measured specimen, the student will graph the data, list the variables, eliminate variables, and state the controls used.

GOAL 4.0: The student will develop an understanding and appreciation for the nature of life.

Competencies	SAMPLE Performance Indicators
4.1 The student is able to demonstrate a knowledge of the chemical basis of life.	4.1.1 Given the task, the student will identify elements, compounds, mixtures basic to life.
4.2 The student is able to demonstrate the knowledge of the relation of the elements to the energy of living things.	4.2.1 Given the task, the student will trace the sun's energy and state the energy conversions that maintain life systems.
4.3 The student knows that cells are composed of elements (atoms) from the earth's atmosphere and crust.	*4.3.1 - 4.10.1 Given lab situations, the student will set up the labs, follow directions, and state the conclusions necessary to accomplishing the competency.
4.4 The student knows that cells are by definition the basic units of living structures.	

4.5 The student knows that in some multicellular organisms, cells are not organized into tissues and organs (e.g. organisms of the protista).

*4.6 The student knows the parts of a generalized cell, plant, or animal.

*4.7 The student is able to prepare materials so that they may be seen through a microscope.

4.8 The student is able to discriminate between objects of biological origin and artifact of slide preparation while looking through a microscope.

4.9 The student knows that some cells have no nucleus (e.g. viruses).

4.10 The student knows modern instruments used to study molecular structure of cells (e.g. electron microscope).

4.11 The student is able to demonstrate a knowledge of cell functions.

4.11.1 Given the task, the student will state the meanings of terms used in biology to identify general cell functions (e.g. metabolism, reproduction, response).

4.11.2 Given a series of labs, the student will describe the ways in which substances move through the cell membranes (e.g. diffusion, active transport, ingestion, excretion).

4.11.3 Given the lab, the student will state that the rate of osmosis is affected by change of many factors (e.g. temperature, concentration of solution, membrane permeability, energy expended by the cell, size of the molecule in the solute).

4.11.4 Given the task, the student will state the interdependence of living things and their environment is related to the transformation of matter chemically from one form to another.

4.11.5 Given the task, the student will describe the sequence of chemical reactions involved in photosynthesis.

GOAL 5.0: The student will develop an understanding of the continuity of life.

Competencies	SAMPLE Performance Indicators
5.1 The student is able to demonstrate a knowledge of the basic process of inheritance and evolution.	5.1.1 Given a list of personal traits, the student will distinguish between those which are inherited and those which are acquired.
	5.1.2 Given the laws of heredity, the student will apply them to genetic problems (Punnett square) of plant and animal inheritance.
	5.1.3 Given a series of lab exercises, the student will apply the laws of heredity to human population studies.
	5.1.4 Given the task, the student will identify the environmental factors that produce mutations, and explain their importance to the survival of the mutant.
	5.1.5 Given the task, the student will explain the advantages of sexual reproduction and the recombination of genes which favors biological success.
*5.2 The student knows reasons for the importance of the evolution model to biological sciences.	
*5.3 The student knows the main contributors to our present evolution model.	
5.4 The student knows that Darwin's Theory of natural selection involves such concepts of overpopulation, variation, fitness to meet environmental stress, inheritance of trait, and genetic mutation.	

GOAL 6.0: The student will develop an understanding and appreciation of the diversity of life.

Competencies	SAMPLE Performance Indicators
*6.1 The student is able to identify characteristics used to group plants and animals.	*6.1.1 Given a list of living things, the student will identify them according to the system of classification.
6.2 The student is able to demonstrate a knowledge of individual organisms on the single cell level.	6.2.1 Given a set of lab exercises, the student will explore viruses, bacteria, protozoa, fungi algae.
6.3 The student is able to demonstrate a knowledge of how microorganisms affect our lives, with special emphasis on infectious diseases.	6.3.1 Given a task, the student will relate the economic importance of microorganisms.
6.4 The student is able to demonstrate a knowledge of mosses, ferns, and seed plants.	6.4.1 Given the series of labs, the student will understand the role of mosses, ferns and seed plants in our environment.
	6.4.2 Given the task of collecting wildflowers, the student will make a definitive collection.
6.5 The student is able to demonstrate a knowledge of invertebrates with special emphasis on their value or harm to man.	6.5.1 Given a series of labs, the student will explore the invertebrate world relating their importance to man.
6.6 The student is able to demonstrate a knowledge of the vertebrate world, with special emphasis on their value or harm to man.	6.6.1 Given labs and tasks, the student will explore the world of vertebrates relating their importance to man.
6.7 The student is able to understand the role of biotic communities in relation to man's responsibility to his environment.	6.7.1 Given examples, the student will identify the role of each organism in a biotic community.
	6.7.2 Given a task, the student will identify man's responsibility to his environment.
6.8 The student knows ways in which human activities can modify both the quantity and quality of environmental factors needed for human life (*e.g.* using up resources; disposing of wastes; storing and testing chemical, biological, and nuclear weapons).	

6.9 The student is able to evaluate his or her own behavior in terms of its effects on present and future environment.

GOAL 7.0: The student is able to discover and learn the knowledge, skills, attitudes, and values necessary to carry out career decisions in the biological sciences.

V. PROCEDURES FOR EVALUATION:

Teacher observation of lab/class performance
Participating and handing in all lab work
Participating in oral discussions/team presentations
Earning the minimum of points in quizzes and tests
Bringing in related items or specimens
Summarizing TV programs
Participating in adapted games
Handing in all study sheets
Answering the questions on the bonus point board
Earning 60% of the total points possible per quarter to pass

Attendance:

Science requires performance. The student may not be able to accomplish the above listed competencies unless he/she attends class regularly. Any student who misses 20 or more classes per semester is in jeopardy of receiving no credit for biology.

Responsibility:

The student is responsible for all assignments and activities in biology. He/she may make up work missed when possible within a specified time period as designated by the teacher. Make up work and late work will generally receive a lower grade as it sometimes proves that the student has already failed his/her responsibility to the class.

Reference: Course Goals in Biological and Physical Science

Tri-County Course Goals

MILWAUKIE HIGH SCHOOL EARTH AND SPACE SCIENCE 1

PLANNED COURSE STATEMENT

TITLE: Earth & Space Science (1st Semester) AREA:
CREDIT: .05 SCHOOL: M.H.S.
PREREQUISITES: None

I. PURPOSE:

The Earth and Space Science student will acquire a basic knowledge of the Earth Sciences, that will give him a basis for understanding and interpreting his environment.

II. COURSE CONTENT:

A. Observing the environment.
B. Earth and moon materials.
C. Change and Earth forces.
D. Measuring the earth.
E. Earth and Moon system.
F. The Solar System.
G. Stars and other suns.
H. Galaxies and the Universe.
I. Oceans
J. Weather

III. LEARNING ACTIVITIES:

A. Laboratory Investigations
B. Demonstrations
C. Audio-visual aided presentations: (overhead, films, filmstrips and slides, chalkboard, models, charts, opague projector, records and tapes.)
D. Lecture and discussion
E. Quizzes and tests
F. Science notebook
G. Research paper

IV. ANTICIPATED LEARNER OUTCOMES:

PROGRAM GOAL: 1. The student will utilize scientific processes.
2. The student will acquire a basic knowledge of Physical Science.

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OBSERVING THE ENVIRONMENT:

Competencies	SAMPLE Performance Indicators
A.1 The student is able to make laboratory observations and inferences from these observations.	A.1.1 Given all the assigned laboratory experiments in physical science, the student will complete them all and turn them in at the assigned time.
A.2 The student is able to interpret data and make predictions from these interpretations.	A.2.1 Given all the Earth & Space assignments and experiments, the student will complete and turn them in at the designated time.
	A.2.2 Given experimental data, the student shall be able to interpolate and extrapolate.
A.3 The student is able to communicate the scientific concepts and ideas taught in this class with the teacher and other students.	A.3.1 Given a set of data, the student will construct a simple graph to summarize that data.
A.4 The student is able to demonstrate a knowledge of the metric system and use common measuring instruments.	A.4.1 Given an object in the lab, the student will appropriately measure its size and mass using the metric units.
A.5 The student knows the meanings of the term "estimate" (i.e. tentative judgment; approximate determination prior to actual measurement).	A.5.1 Given specific tasks, the student will first estimate the length, mass or volume, then use metric tools to verify the estimations.
A.6 The student is able to demonstrate a knowledge of the metric system.	A.6.1 Given a list of metric terms, the student will state the English equivalent.

EARTH & MOON MATERIALS:

Competencies	SAMPLE Performance Indicators
B.1 The student will become aware of the various materials of which the earth if made, the states of matter they assume and their atomic structure.	B.1.1 Given a question on the properties of earth materials the student will answer them 60% correct, and hand in all labs and assignments at the appointed time.
B.2 At the end of this study the student will be able to: 1. Describe the significant similarities and differences between the lithosphere,	

hydrosphere, and
atmosphere.

2. Classify various earth materials according to their origin.

3. Calculate densities, using accurate measurements of volume and mass.

4. Differentiate among atoms, elements, molecules, compounds, minerals, and rocks.

5. Explain how the characteristics of minerals give clues to their atomic structure.

6. Discuss the changes in minerals caused by their environments.

7. Compare the importance of various elements, such as oxygen, on the earth and the moon.

CHANGE AND EARTH FORCES:

Competencies	SAMPLE Performance Indicators
C. 1 The students will be able to recognize basic concepts concerning energy; how it is generated, transferred and absorbed and basic concept concerning gravity and magnetism.	C.1.1 Given questions on the concepts of energy the student will answer correctly 60% of the time, and hand in all labs and assignments in the appointed time.
C.2 After completing this study the student will be able to: 1. Describe how heat is generated in the sun and transferred to the earth. 2. Account for the principal sources of earth's heat energy. 3. Give examples of the three ways heat can be transferred from one place to another.	

4. Use Newton's law of motion to account for common experiences involving inertia, momentum, velocity, speed, and acceleration.
5. Describe the force of gravity.
6. Describe the earth's magnetic field.

MEASURING THE EARTH:

Competencies	SAMPLE Performance Indicators
D.1 The student will gain a perspective about the size and shape of the earth.	D.1.1 Given question on earth measurements the student will answer 60% correct and hand in all labs and assignments at the appointed time.
D.2 At the end of this study the student will: 1. Use linear and angular measurements in establishing location. 2. Demonstrate some comprehesion of scale and of relationships between a model such as a globe and the earth. 3. Construct a topographic map from a three-dimensional model. 4. Use a topographic map to identify variations in landscapes.	

GOAL: The student will gain perspectives of the motion of the earth-moon system and how these motions affect his life.

Competencies	SAMPLE Performance Indicators
E.1 The student is able to describe the basic motions of the earth moon system.	E.1.1 Given questions on the motions of the earth and moon, the students will answer them correctly 60% of the time.

E.1.2 Given labs and assignments relating to the motions of the earth and moon, the students will complete them and hand them all in at the assigned time.

E.2 At the end of this study the students will be able to:

1. Cite proofs that the earth and moon each rotate on an axis and revolve around the sun.
2. Explain the causes of the seasons.
3. Explain what causes the tides.
4. Demonstrate how phases and eclipses of the moon occur.
5. List similarities and differences between the moon and the earth.
6. Analyze the topography of the moon's surface.
7. Give examples of how study of the moon will provide greater understanding of the development of the earth and the solar system.

THE SOLAR SYSTEM:

F.1 The student will gain perspectives about the solar system; its size, origin, planetary groupings and the laws that govern it.

F.1.1 Given questions about the solar system the students will be able to answer 60% correctly and hand in all labs and assignments.

F.2 After this study, the student should be able to:

1. Demonstrate the relative amount of empty space in the solar system compared to the space occupied by the planets.

2. Contrast the characteristics of the two main planet groups.

3. List some physical characteristics of each of the nine planets.

4. Describe how the law of gravitation affects planetary motion.

5. Describe the physical characteristics and motion of asteroids and comets.

6. Contrast the theories of the origin of the solar system.

STARS AS OTHER SUNS:

G.1 The students will gain an overall view of stellar evolution, and a general knowledge of how scientists study stars.

G. 2 At the end of this study the students will be able to:

1. Describe how scientists determine a star's temperature, chemical composition, luminosity, motion, and distance from the earth.

2. Demonstrate parallax and explain how it can be used to measure distance.

3. Compare the sun to other stars.

4. Describe the life cycle of a star.

5. Explain how the mass of a star determines how long it will live.

6. Explain how H-R diagrams support the theory of stellar evolution.

G.1.1 Given questions about stars, the students will answer 60% of them correct and complete all labs and assignments in the appointed time.

GALAXIES AND THE UNIVERSE:

H.1 Students will gain a perspective on the universe, its size, origin and man's plan in it.

H.1.1 Given questions about galaxies and the universe, students will answer 60% correct and complet all labs and assignments in the appointed time.

H.2 At the end of this study the student will:

1. Describe the Milky Way galaxy --its size, shape, rotation, and the sun's location in it--and indicate how scientists obtained this information.

2. Compare our Milky Way galaxy to other galaxies in terms of size and shape.

3. Explain why looking at starlight is like looking into the past.

4. Name the two most common chemicals in the universe.

5. Discuss the significance of the Doppler effect as evidence for an expanding universe.

6. Discuss common examples of relativity.

WATER IN THE SEA:

I.1 The students will learn about sea water, currents, waves and circulation in the sea.

I.1.1 Given questions about the oceans, students will answer 6C% correct, and they will also complete all labs and assignments in the appointed time.

I.2 After this study the students will be able to:

1. Compare the physical and chemical properties of fresh water and seawater.

2. Describe the processes that change the salinity, temperature and density of seawater.

3.Explain the causes of surface and deep ocean circulation.

4. Use a model to demonstrate the movement of water particles in survace waves.

5. Trace the path of energy from the sun to ocean waves and currents.

6. Explain how atmospheric circulation and varying densities of seawater cause ocean circulation.

WATER CYCLE:

J.1 The student will learn how the water cycle functions and how it affects our lives.

J.1.1 Given a test about the water cycle the student will score at least 60% and will also hand in all labs and assignments in the appointed time.

J.2 At the end of this study the student will be able to:

1. Demonstrate how the earth's shape and orientation in space determine the distribution of incoming radiation.
2. Demonstrate how land and water absorb energy at different rates.
3. Explain how unequal heating of land and water, aided by gravity, produce convective circulation.
4. Make a model that demonstrates how the earth's rotation modifies basic convective circulation to produce easterly and westerly winds.
5. Show how the processes of evaporation, condensation, and precipitation are involved in the water cycle.
6. Describe the energy changes during evaporation and condensation.
7. Explain why both energy and air motions are necessary for evaporation to occur.

8. Describe the life cycle of a frontal cyclone and the typical weather it produces.

9. Describe how water infiltrates the ground and becomes capillary and gravity water.

10. Describe in general terms how flood forecasts are made.

V. THE STUDENT SHOULD DEVELOP APPROPRIATE VALUES:

1. The student values behavior based on rational and informed judgements, choices, and decisions.

2. The student knows what things, ideas, and behaviors he or she values.

3. The student knows that different individuals value different things, ideas, and behaviors to satisfy essentially similar basic needs.

4. The student is able to use scientific knowledge and processes to resolve conflicts in personal values.

5. The student is able to distinguish between value statements and descriptive or definitional statements.

6. The student is able to identify the different value positions represented in a social issue.

7. The student is able to weigh the merits of information supporting value positions in terms of relevant criteria.

8. The student values scientific knowledge and processes which aid in identifying basic needs of societies.

9. The student values a society in which individuals participate in making decisions which will affect them.

10. The student values problem solving.

11. The student values intellectual flexibility in dealing with complexity (i.e. the ability to change, expand, or construct new frames of reference to match situations).

12. The student values the uniqueness or worth of individual lives.

13. The student values human feelings.

14. The student values the needs of others.

15. The student values accepting responsibility for the consequences of his/her decisions and actions.

16. The student values self.

17. The student values creativity and imagination: the pleasure of manipulating and extending ideas.

18. The student values the pleasure of learning.

19. The student values aesthetic experiences.

20. The student values novelty: new perceptions, experiences, ideas.

21. The student values the continual expansion of human knowledge about reality.

22. The student values full use of all channels of human perception.

23. The student values full and appropriate use of sense extenders.

24. The student values freedom from bias: perception of reality which is not limited or distorted by premature judgments or assumptions.

25. The student values symbolic representations (e.g. words and mathematical symbols).

26. The student values the ability to distinguish between relevant and irrelevant data when validating a representation of fact, opinion, or conclusion.

27. The student values organization of representations (conceptual schemes, models, classification systems, etc.) which permit recall and retrieval of information.

28. The student values the restructuring of behavior in response to more adequate and accurate information about situations.

29. The student values accuracy and openness of communication.

30. The student values the full and appropriate use of scientific information retrieval systems.

VI. PROCEDURES FOR EVALUATION:

A. Tests: written, oral, laboratory
B. Observation of classroom performance
C. Laboratory writeups
D. Worksheets
E. Research papers
F. Notebook
G. Attendance

In order to pass the course at a minimum level, the student must pass the tests which apply to a particular competency at a (D) level, turn in all the assigned work, and perform adequately in class. Class performance includes a student's actions in class and attendance and tardies. Over ten absences in a semester will cause a student to receive a permanent incomplete in competency (I).

To receive grades of A, B, or C, the student must complete the minimums and also receive the following percentages of the total points possible for all of the assignments.

90 - 100% = A
80 - 89.9% = B
70 - 79.9% = C
60 - 69.9% = D

Source of reference: Tri-County Course Goals

MILWAUKIE HIGH SCHOOL EARTH AND SPACE SCIENCE 2

PLANNED COURSE STATEMENT

TITLE: Earth & Space Science
Semester 2
CREDIT: .50
PREREQUISITE: First Semester-Earth
and Space Science

AREA: Scientific & Technological
Processes

SCHOOL: MHS

I. PURPOSE

The Earth and Space Science student will acquire a basic knowledge in Earth and Space Science. This will give him a basis for understanding and interpreting his environment.

II. COURSE CONTENT

A. Weathering and Erosion
B. Sedimentation
C. Building Mountains
D. Earthquakes and the Earth's Interior
E. Rocks and Minerals
F. Time and Earth's Biography
G. Ecology and the Environment

III. LEARNING ACTIVITIES

Laboratory investigations: qualitative and quantitative observations.
Demonstrations: laboratory procedures, concepts and scientific phenomena.
Audio-visual aided presentations: overhead, films, filmstrip, and slides; chalkboard, models, charts, opaque projector, records, and tapes
Lecture and discussion
Quizzes, tests
Science notebook
Research papers

WEATHERING & EROSION

A.1 The student will become aware of the constant changing of the earth crust by the process of weathering & erosion.

A.2 At the end of this study the student will be able to:

1. Explain what happens to rocks and minerals as they weather.

A.1.1 Given a test about weathering and erosion, the student will score at least 60% and will also hand in all labs and assignments at the appointed time.

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2. Recognize weathering products and discuss how they differ from the parent rock.

3. Describe how resistant minerals are separated from less resistant minerals, and conditions under which they are formed.

4. Compare the erosive effects of water, ice, and wind on the earth's surface.

5. Describe the role of gravity in erosion.

SEDIMENTATION

B.1 The student will learn the processes and energy exchanges in sedimentation and develop a model of the ocean basin and the sediments that form in different parts of the ocean floor.

B.1.1 Given a test about sedimentation, the student will score at least 60% correct and will also hand in all labs and assignments at the appointed time.

B.2 At the end of this study the student will be able to:

1. Construct or describe a model of an ocean basin.

2. Contrast the depositional processes that take place near shore, on the continental shelf, and on the continental slope.

3. Construct a model of turbidity currents.

4. Contrast sediments deposited on the continental margins and those in deep ocean basins.

5. Give examples of events that could change sea level.

MOUNTAIN BUILDING:

C.1 The student will become aware of the different types of mountain building forces and will be able to place the forces in the greater pattern of general crustal movement.

C.1.1 Given a test about mountain building and crustal movement, the student will score at least 60% correct and will also turn in all labs and assignments at the appointed time.

A.2 After completing this study, the student will be able to:

1. Describe how mountains develop from geosynclines through the stages of deposition, deformation, and uplift.

2. Explain how mid-ocean ridges, deep-sea trenches, earthquake activity, and geosynclinal mountains might be caused by movements of the earth's crust.
3. Compare modern areas of shallow-water deposition with ancient geosynclinal basins.
4. Locate belts of crustal mobility on a globe and explain why they are seldom in the middle of continents.
5. Describe some basic causes of crustal unrest within continents and ocean basins.
6. Discuss the importance of magnetic stripes in rocks to the theory of plate tectonics.

EARTHQUAKES AND THE EARTH'S INTERIOR

D. 1 Students will investigate various ways that scientists study the earths interior, and will develop a general knowledge of what has been learned about the earth's interior.

D.2 After completing this study, the student will be able to:

1. Give several reasons why scientists study the interior of the earth.
2. Explain how seismic data is used to determine the earth's internal structure.
3. Determine earthquake epicenter locations from the differences between P and S wave.
4. Construct or describe a general model of the earth's interior.

D.1.1 Given a test about earthquakes and the earth's interior, the student will score at least 60% correct and will also hand in all labs and assigned work at the appropriate time.

ROCKS AND MINERALS

E.1 The students will learn the basic igneous rock building processes, volcano types and procedures for identifing common minerals.

E.1.1 Given a test about rocks and minerals, the student will score at least 60% correct and will hand in all labs and assigned work at the appointed time.

E. 2 At the end of this study the student will be able to:

1. Describe the various types of volcanoes found in Oregon.
2. Distinguish between the different types of lava.
3. Distinguish between plutonic and volcanic rocks in terms of occurrence, mineral and chemical composition, and texture.
4. Discuss how temperature, pressure, and mineral solutions affect rocks at the surface and below.
5. Identify some of the most common rock forming minerals.

MEASURING TIME

F.1 The student will gain perspective on the age of the earth, on man's place in time and techniques established for measuring time.

F.1.1 Given a test on time and its measurment the student will get 60% correct and will also hand in all labs and assigned work at the appointed time.

F.2 At the end of this study the student will be able to:

1. Propose methods to measure the duration of events and the intervals between them.
2. Explain why time must be divided into units.
3. Use radioactive decay data to determine the age of rocks.

4. Construct a time scale that tells both the relative and exact age of events.

5. Use the Geologic Time Scale to compare the ages and duration of various segments of geologic time.

6. Determine the origin of rocks from observing actual rocks or illustrations of outcrops.

7. Distinguish the top of a rock layer from the bottom.

8. Correlate rock layers using fossils, rock types, position in a sequence, or other means.

9. Reconstruct the sequence of a series of geologic events from cross sections of an area.

G.1 The student will understand the basic concepts of, and relationships between genetic change, artificial selection, and natural selection.

G.1.1 Given basic questions on genetic change, artificial and natural selection, the student will answer them correctly 60% of the time.

G.2 At the end of this study the student will be able to:

1. Know historic contributions of sciences and scientists to the development of theories about the origins of life.

2. Analyze or clarify issues related to validation or communication of scientific information about origins of life.

3. Know reasons for the importance of the evolution model to the biological sciences.

4. Know factors of the evolutionary process which produce changes within a species.

5. Know that Darwin's theory is based on the principle of uniformitarianism: that existing processes, acting in the same manner and intensity as at present have been constant throughout time and are sufficient to account for all geological and biological changes.

6. Know that over a period of time, stable populations adapt genetically to their environments.

7. Know that Darwin's theory of natural selection involves such concepts as overpopulation, variation, fitness to meet environmental stress, inheritance of traits, and genetic mutation.

G.3.1 The student will understand the basic concepts of population ecology.

G.3.1.1 Given questions on population ecology, the student will respond correctly 60% of the time.

G.3.2 At the end of this study the student will be able to:

1. Know factors which influence population growth.

2. Know the effects of uncontrolled population growth on the individuals in the population and on other populations.

3. Analyze problems of human population growth.

4. Know that mortality rates influence population growth rates.

5. Know factors which affect the mortality rates of populations.

G.4 The student will understand basic ecological concepts and processes.

G.4.2 At the end of this study the student will be able to:

1. Know that organisms in a community may be categorized as producers, consumers, and decomposers.
2. Know the relationship between producers and consumers in a community.
3. Interpret data collected from natural environments regarding producer-consumer and biotic-abiotic relationships.
4. Know organisms and interactions characteristic of communities in various major biomes or habitats.
5. Know meanings of terms conventionally used in descriptions or analyses of ecosystems.

G.4.1 Given questions on the concepts and processes of ecology, the student will answer correctly 60% of the time.

REX PUTNAM HIGH SCHOOL SCIENCE 1 (UNIFIED SCIENCE)

PLANNED COURSE STATEMENT

TITLE: Science 1	AREA: Science
CREDIT: .50	SCHOOL: RPHS
PREREQUISITES: None	

I. PURPOSE:

The Science 1 student will increase his/her understanding of the scientific approach to developing and using knowledge. This will be achieved by a variety of activities and experiences that will enable the learner to acquire some of the basic knowledge and skills associated with the:

1. Biological sciences
2. Physical sciences
3. Scientific/Technological processes

II. COURSE CONTENT:

The course is comprised of six instructional units organized around the themes of:

1. Observation
2. Perception
3. Measurement
4. Model
5. Radioactivity
6. Cell

III. LEARNING ACTIVITIES:

1. Laboratory investigations
2. Demonstrations (Teacher and Student)
3. Audio-visual aids (Including films, posters, charts, graphs, audio tapes, filmstrips, overhead projector, laboratory models, and chalkboard)
4. Discussions
5. Lectures
6. Reading
7. Computer (Experiments, simulated experiments, computation, data display, data storage, graphing, etc.)
8. Games
9. Laboratory writeups
10. Exams/Quizzes
11. Reports/Projects

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IV. ANTICIPATED LEARNER OUTCOMES: (Those competencies designated with an asterisk are certified as fulfilled when a student has earned a passing grade for Science 1.)

Competencies	SAMPLE Performance Indicators
*1. OBSERVING AND INFERING The student is able to make laboratory observations and make inferences from these observations. (District competency 1.7.1.2)	1.1 Given a list of observations and inferences, the student will be able to correctly identify the inferences. 1.2 Given an appropriate laboratory situation or demonstration, the student will make several observations and at least one reasonable inference from those observations.
2. COMMUNICATING The student is able to communicate scientific concepts and ideas with the teacher and fellow students. (District competency 1.7.1.3)	2.1 The student can write legible, understandable laboratory reports following the given report guidelines. 2.2 The student will satisfactorily define at least 80% of the items in the following list: 1. Inference 2. Qualitative observation 3. Quantitative observation 4. Mean 5. Validity 6. Reliability 7. (Identify) Standard S.I. units for length, mass, weight, time, and temperature 8. Model 9. Radioactivity 10. Atom 11. Mitosis 12. Cell 13. Living 14. Measurement 15. Microscope
3. INTERPRETING AND PREDICTING The student is able to interpret data and make predictions from these interpretations. (District competency 1.7.1.4)	3.1 Given appropriate experimental data, the student will: 1. Calculate the mean 2. Report the range 3. Construct a properly labeled graph 3.2 Given a line graph, the student will successfully extrapolate to a designated value for one of the variables.

4. RECOGNIZING VARIABLES

The student is able to recognize variables and predict what would happen when selected variables are altered. (District competency 1.7.1.5)

4.1 Given a description of an experiment and a list of observable aspects of the situation, the student will be able to correctly identify the variables.

4.2 Given the description of an experiment and partial data, the student will reasonably predict the result of varying selected variables in designated manners.

5. EXPERIMENTING

The student is able to set up and complete an experiment. (District competency 1.7.1.6)

5.1 Given written instructions and the necessary equipment and materials, the student will:

1. Assemble the apparatus correctly
2. Manipulate the designated variable(s) and record the observations
3. Adhere to all standard and special laboratory safety practices
4. Disassemble the apparatus and satisfactorily clean the working area

*6. RECOGNIZING AND USING MODELS

The student is able to recognize and use scientific models. (District competency 1.7.1.7)

6.1 The student will describe the general circumstances under which a scientific model is used for explanatory purposes.

6.2 Given a scientific model (e.g., atomic). the student will use it to:

1. Predict the results of a given test
2. Devise an explanation for a given observation
3. Explain an observed demonstration

*7. MEASURING

The student is able to demonstrate a knowledge of the metric (system) and use common measuring instruments. (District competency 1.7.1.8)

7.1 The student will demonstrate the ability to properly use the appropriate measuring device to satisfactorily measure:

1. Length
2. Mass
3. Weight
4. Volume
5. Time
6. Temperature

7.2 The student can provide appropriate S.I. units for area and speed.

7.3 The student will correctly apply S.I. prefixes when converting volume, length, and mass measurements (e.g., converting a given number of liters to milliliters).

V. PROCEDURES FOR EVALUATION:

1. Competencies

Satisfactory completion of the course minimum competencies is determined on the basis of student performance on a designated set of performance indicators for each competency. A passing grade for the course indicates successful completion of all designated minimum competencies.

2. Course

Overall course performance level is judged on the basis of a point system. Students earn points from a variety of class activities and procedures, such as:

(1) Laboratory write-ups
(2) Short term assignments (e.g., work sheets, question sets, problem solving sets)
(3) Examinations
(4) Quizzes
(5) Level and quality of classroom and laboratory participation

With reasonable flexibility granted to the individual classroom teacher for purposes of addressing unusual specific situations, the following scale determines the letter grade earned for the course.

Percentage of Total Possible Points	Letter Grade
90 - 100	A
80 - 89	B
60 - 79	C
50 - 59	D
Below 50	No Credit

REX PUTNAM HIGH SCHOOL SCIENCE 2 (UNIFIED SCIENCE)

PLANNED COURSE STATEMENT

TITLE: Science 2 AREA: Science
CREDIT: .50 SCHOOL: RPHS
PREREQUISITE: Science 1

I. PURPOSE

The Science 2 student will increase his/her understanding of the scientific approach to developing and using knowledge. This will be achieved by a variety of activities and experiences that will enable the learner to acquire some of the basic knowledge and skills associated with the:

1. Biological sciences
2. Physical sciences
3. Scientific/Technological processes

II. COURSE CONTENT:

The course is comprised of six instructional units organized around the themes of:

1. Genetics
2. Classification (General)
3. Classification (Characteristic properties of matter)
4. Heat energy
5. Energy
6. Mice

III. LEARNING ACTIVITIES:

1. Laboratory investigations
2. Demonstrations (Teacher and Student)
3. Audio-visual aids (Including films, posters, charts, graphs, audio tapes, filmstrips, overhead projector, laboratory models, and chalkboard)
4. Discussions
5. Lectures
6. Reading
7. Computer (Experiments, simulated experiments, computation, data display, data storage, graphing, etc.)
8. Laboratory writeups
9. Examinations/Quizzes
10. Reports/Projects

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IV. ANTICIPATED LEARNER OUTCOMES: (Those competencies designated with an asterisk are certified as fulfilled when a student has earned a passing grade for Science 2.)

Competencies	SAMPLE Performance Indicators
*1. CLASSIFYING The student is able to fit an organism, object or substance into a scientific classification scheme. (District competency 1.7.1.1)	1.1 Given 10 objects of the same general type (e.g., rocks, microorganisms), the student will devise a classification scheme that will effectively distinguish the objects. 1.2 Given some of the physical and chemical characteristics of a compound, the student will be able to tentatively identify the compound by utilizing either a computerized or keysort card classification scheme.
2. OBSERVING AND INFERING The student is able to make laboratory observations and make inferences from these observations. (District competency 1.7.1.2)	2.1 Given a list of observations and inferences, the student will be able to correctly identify the inferences. 2.2 Given an appropriate laboratory situation or demonstration, the student will make several observations and at least one reasonable inference from those observations.
*3. COMMUNICATING The student is able to communicate scientific concepts and ideas with the teacher and fellow students. (District competency 1.7.1.3)	3.1 The student can write legible, understandable laboratory reports following the given report guidelines. 3.2 The student will satisfactorily define at least 80% of the items in the following list: 1. Genotype and phenotype 2. Dominant and recessive characteristics 3. Mutation 4. Classification 5. Density 6. Melting Point and Boiling Point 7. Calorie 8. Hypothermia 9. Methods of heat transfer 10. Potential and kinetic energy 11. Joule 12. Kilowatt-hour 13. Energy efficiency 14. Maturation 15. Healthy environment for laboratory animals (e.g., mice)

*4. INTERPRETING AND PREDICTING The student is able to interpret data and make predictions from these interpretations. (District competency 1.7.1.4)	4.1 Given genotype and phenotype information for the parent generation, the student will describe the probable characteristics of the progeny. 4.2 Given the temperature and time data from heating an initially solid substance, the student will: 1. Construct a properly labeled graph 2. Identify the melting point of the substance 3. Identify the boiling point of the substance
*5. RECOGNIZING VARIABLES The student is able to recognize variables and predict what would happen when selected variables are altered. (District competency 1.7.1.5)	5.1 Given a description of an experiment and a list of observable aspects of the situation, the student will be able to correctly identify the variables. 5.2 Given the description of an experiment and partial data, the student will reasonably predict the result of varying selected variables in designated manners.
*6. EXPERIMENTING The student is able to set up and complete an experiment. (District competency 1.7.1.6)	6.1 Given written instructions and the necessary equipment and materials, the student will: 1. Assemble the apparatus correctly 2. Manipulate the designated variable(s) and record the observations 3. Adhere to all standard and special laboratory safety practices 4. Disassemble the apparatus and satisfactorily clean the working area
7. RECOGNIZING AND USING MODELS The student is able to recognize and use scientific models. (District competency 1.7.1.7)	7.1 Given a list of phenomena and another list of models, the student will choose one phenomenon and identify one of the models as appropriate for explaining or further investigating the phenomenon.

7.2 Given a scientific model (e.g., Mendelian genetics), the student will use it to:

1. Predict the results of a given test
2. Devise an explanation for a given observation
3. Explain an observed demonstration

8. MEASURING

The student is able to demonstrate a knowledge of the metric (system) and use common measuring instruments. (District competency 1.7.1.8)

8.1 The student will demonstrate the ability to properly use the appropriate measuring device to satisfactorily measure:

1. Length
2. Mass
3. Weight
4. Volume
5. Time
6. Temperature

8.2 The student can provide appropriate S.I. units for density and specific heat.

8.3 The student will correctly apply S.I. prefixes when converting volume, length, mass, and time measruements (e.g., converting a given number of grams to kilograms).

APPENDIX C

TEACHER MATERIALS AND QUESTIONNAIRES

1. Teacher Questionnaire
2. Orientation Meeting Information Sheet
3. Testing Instruction Sheet
4. Posttest Testing Instruction Sheet
5. Teacher Questionnaire II

TEACHER QUESTIONNAIRE

TEACHER QUESTIONNAIRE

NAME____
(Your name will not be used; I need it here simply to monitor the return of the questionnaires.)

SCHOOL: Clackamas Milwaukie Putnam

SCIENCE TEACHING THIS YEAR:

SEMESTER 1:

Course(s) Taught	Number of Sections

SEMESTER 2:

Course(s) Taught	Number of Sections

SCIENCE TEACHING EXPERIENCE:

Total years (not including this year) of high school (grades 9-12) science teaching experience (teaching one or more science courses)

At your present school____ Elsewhere____

Years of high school teaching experience in the science course(s) you are teaching this year

Course(s)	Years Taught at Present School	Years Taught Elsewhere

FORMAL ACADEMIC PREPARATION

College or University Degrees Earned	Year

ORIENTATION MEETING INFORMATION SHEET

CLACKAMAS HIGH SCHOOL

Science Department

PURPOSE OF RESEARCH: This research is being conducted to partially fulfill the requirements of a Ph.D. program for Dave Cox and make a new contribution to the existing science education research knowledge base.

INVESTIGATOR: Dave Cox

UNIVERSITY AFFILIATION: The Ohio State University, Columbus, Ohio

QUESTIONS TO BE ADDRESSED:

1. Does the type of science that serves as the basis of the classroom learning experiences during the required year of science have any significant relationship to the process skill competency performance level achieved by students?
2. Does the grade level where science is last required have a significant relationship to the student performance level attained on science process skill competencies?
3. What science process skill competency performance level do students have one, two, or three years after the last required science course has been completed?
4. Do elective science courses completed after the last required year of science have a significant relationship to the level of performance on science process skill competencies?

RELEVANT CALENDAR: September 11, 1981-Pretesting of all students enrolled in required science courses with the investigator developed Science Process Comptency Test, which is a 24 item multiple-choice test measuring performance level on district science process competencies 1.7.1.1, 1.7.1.2, 1.7.1.4, 1.7.1.5, 1.7.1.7, and 1.7.1.8. The test will be administered by the classroom teacher and should require no more than a total of 45 minutes.

June 2, 1982-------Posttesting of all students enrolled in required science courses. The same test and procedure as used in the pretesting will be utilized.

DISTRICT USE OF RESEARCH: None specified as certain. The only possible use discussed has been to fulfill the following requirement from the new Standards for Public Schools.

> "Assess student performance on selected program goals in at least language arts, mathematics, science and social studies in two elementary grades and one secondary grade, prior to the selection of district textbooks..."

TESTING INSTRUCTION SHEET

TESTING INSTRUCTION SHEET

A. MATERIALS

You will be provided with the following materials.

1. 30 Test Booklets
2. Student Information Sheets
3. Student Answer Sheets (General Purpose NCS Answer Sheets)
4. 24 Pencils
5. Large Envelopes

B. STUDENT INFORMATION SHEETS

Have each student complete a Student Information Sheet prior to handing out the test booklets and answer sheets. Students are to either CIRCLE the appropriate information or WRITE it in the blank spaces provided.

C. ANSWER SHEETS

Only Side 1 of the General Purpose-NCS-Answer Sheet will be used. USING A PENCIL ONLY, have students write the FIRST LETTER of their LAST NAME followed by their BIRTH DATE ABOVE where "Name" is printed in the upper left-hand corner. For example, student Leslie Doe would write

D 3/23/66
NAME (Last, First, M.I.)

This is the only information that students are to place on the answer sheet.

D. TEST BOOKLETS

Hand out the test booklets, reminding students not to open them until told to do so. PLEASE READ THE FOLLOWING TO YOUR STUDENTS.

> Students from all three high schools in the district will be taking this test. It is designed to measure your understanding of science process skills, such as measuring and classifying. While it is not a graded part of your class work, it is important that you do the very best that you can on the test. For each of the 24 questions, you are to select the ONE best answer and darken the space corresponding to it on your answer sheet. If you are not sure of an answer, make the best guess that you can. Remember to use only pencil, make your marks dark, and fill the circle completely. Erase cleanly any answer you wish to change. Please do not mark or write on the test booklet. You will have the remainder of the class period to complete the test. Turn the page, read the instructions, and begin answering the questions.

E. COLLECTION OF MATERIALS

1. Please place the Student Information Sheets and answer sheets for each class together in a separate envelope.
2. Be sure that all test booklets are returned at the end of each period.
3. Please make every effort to recover pencils that are borrowed by students.
4. Please return all materials to me at the end of the school day or when you have completed testing for the day.

F. ATTENDANCE

Please record class numbers and absences on the attached sheet and return it to me at the end of the day.

G. QUESTIONS, PROBLEMS, ETC.

I will be in your building all day during the testing. Should you have any questions, need additional materials, etc., I will be located________

____.

Thank you very much for your cooperation on this project.

H. NOTES

TEACHER

SCHOOL

PERIOD	ENROLLED	NAMES OF ABSENT STUDENTS
1		
2		
3		
4		
5		
6		
7		

POSTTEST TESTING INSTRUCTION SHEET

POSTTEST TESTING INSTRUCTION SHEET

A. MATERIALS

You will be provided with the following materials:

1. 30 Science Process Competency Test booklets
2. 125 Science Process Test Answer Sheets
3. 25 Student Information Sheets
4. 24 Pencils
5. 5 Large Envelopes
6. 1 Attendance Reporting Sheet
7. 1 Testing Conditions Reporting Sheet

B. ANSWER SHEETS

Students may use either pencil or pen when marking their answer sheets. Pencils are preferable, however, since their use minimizes problems when changing answers. If a pen is used, any answer that is changed should have an "X" placed on it. Students are not to mark or write in the upper portion of the answer sheet. In the lower left-hand corner of the answer sheet, students are to write the FIRST LETTER of their LAST NAME followed by their BIRTH DATE. For example, student Leslie J. Doe would write

ID: D 3/23/66
(First letter of last name) (birth date)

Other than their answers to the 24 test questions, this is the only information that students are to place on the answer sheets. The questions on the page stapled to the answer sheet are to be answered after the test has been completed.

C. TEST BOOKLETS

Hand out the test booklets, reminding students not to open them until told to do so. PLEASE READ THE FOLLOWING TO YOUR STUDENTS.

> Students from all three high schools in the district will be taking this test. It is designed to measure your understanding of some of the science process skills, such as classifying and measuring. While the test is not a graded part of your class work, it is important that you do the very best that you can when answering the questions. The results of the testing will only be useful if everyone makes their best effort. For each of the 24 questions on the test, you are to select the ONE best answer and darken the space corresponding to it on your answer sheet. If you are not sure of an answer, make the best guess that you can. Erase or place an "X" on any answer you wish to change. PLEASE DO NOT MARK OR WRITE ON THE TEST BOOKLETS. Stapled to your test answer sheet is a page containing two questions. Please

answer these questions after you have completed the test. You will have the remainder of the class period in which to complete the test. Turn the first page of your test booklet, read the instructions, and begin answering the questions.

D. STUDENT INFORMATION SHEETS

The only students who need to fill out the Student Information Sheet II are those who DID NOT take the pretest. They are to either circle the appropriate information or write it in the blank spaces provided.

E. COLLECTION OF MATERIALS

1. Please place the test answer sheets and Student Information Sheets for EACH CLASS IN A SEPARATE ENVELOPE.
2. Be sure that all test booklets are returned at the end of each class period.
3. Please make every effort to recover pencils that are borrowed by students.
4. Please return all materials to me at the end of the school day or when you have completed testing for the day.

F. ATTENDANCE REPORTING SHEET

Please record the requested class numbers and names of students who are absent and return the sheet to me at the end of the day.

G. TESTING CONDITIONS REPORTING SHEET

Please make any appropriate comments for any class period in the space provided, and return the sheet to me at the end of the day.

H. QUESTIONS, PROBLEMS, ETC.

I will be in your building all day during the testing. Should you have any questions, need additional materials, etc., I will be in the GUIDANCE OFFICE AREA. Thank you very much for your cooperation on this project.

I. NOTES AND REMINDERS

ATTENDANCE REPORTING SHEET

TEACHER

SCHOOL

PERIOD	ENROLLED	NAMES OF ABSENT STUDENTS
1		
2		
3		
4		
5		
6		
7		

TESTING CONDITIONS REPORTING SHEET

TEACHER

SCHOOL

Please list below any unusual circumstances or events that occured during any class period on the designated testing day. In addition, please note any significant variations in testing procedure, length of working time, etc. Thank you!

PERIOD	UNUSUAL CIRCUMSTANCES, EVENTS, VARIATIONS IN TESTING
1	
2	
3	
4	
5	
6	
7	

TEACHER QUESTIONNAIRE II

TEACHER QUESTIONNAIRE II

NAME: ______________________________

(Your name will not be used; I need it here simply to monitor the return of the questionnaires.)

SCHOOL: Clackamas Milwaukie Rex Putnam

1. TIME DEVOTED TO THE SCIENCE PROCESS SKILL COMPETENCIES

Please make an estimate of the percentage of your total instructional time devoted to the science process skills identified in the district minimum graduation competencies in the scientific/technological processes. Place an "X" on the instructional time continuum to represent your estimate.

0 10 20 30 40 50 60 70 80 90 100

No Time ______________________________ Full Time

If you marked LESS THAN 10%, please write a more precise estimate in the space below.

__________%

2. CHANGE IN TIME OR EMPHASIS

Did you increase over your usual amount either the time spent or the emphasis on the science process skills this year?

YES NO

If YES, did you increase time? emphasis? both time & emphasis?

(circle your choice above)

3. INSERVICE

Have you participated in any building or district level inservice activity devoted to the district high school science program goal and/or the science process skill minimum graduation competencies?

YES NO

If YES, please check all appropriate responses below.

☐ Inservice relative to the district's high school science program goal

☐ Inservice relative to the district's minimum graduation competencies in the scientific/technological processes

☐ Building level inservice

  ☐ Within the last year

  ☐ Between 1 and 3 years ago

  ☐ 4 or 5 years ago

  ☐ More than 5 years ago

☐ District level inservice

  ☐ Within the last year

  ☐ Between 1 and 3 years ago

  ☐ 4 or 5 years ago

  ☐ More than 5 years ago

4. CLASSES/WORKSHOPS

Have you participated in any class or workshop that was devoted entirely or had a major component devoted to the science process skills?

YES NO

If YES, please check all appropriate responses below and provide the requested accompanying information.

☐ Class

Location: ____________________

Title: ____________________

☐ Workshop

Location: ____________________

Title: ____________________

Completed

  ☐ Within the last year

  ☐ Between 1 and 3 years ago

  ☐ 4 or 5 years ago

  ☐ More than 5 years ago

APPENDIX D

VALIDATION PANEL

1. Letter and Instructions to Validation Panel Members
2. Validation Panel Worksheet

LETTER AND INSTRUCTIONS TO VALIDATION PANEL MEMBERS

Milwaukie, Oregon 97222
July 23, 1981

Dear ,

Thank you very much for agreeing to assist in the validation of my dissertation instrument. The test is designed to measure the performance level of students in grades 9 and 10 relative to a set of science competencies adopted by the North Clackamas School District. These science process competencies are

1. The student is able to fit an organism, object or substance into a scientific classification scheme.
2. The student is able to make laboratory observations and make inferences from these observations.
**3. The student is able to communicate scientific concepts and ideas with the teacher and fellow students.
4. The student is able to interpret data and make predictions from these interpretations.
5. The student is able to recognize variables and predict what would happen when selected variables are altered.
*6. The student is able to set up and complete an experiment.
7. The student is able to recognize and use scientific models.
8. The student is able to demonstrate a knowledge of the metric (system) and use common measuring instruments.

*The intent of competency 6 is for the student to follow a given set of instructions that require the physical assembly, manipulation, reading, etc. of equipment and materials in order to satisfactorily complete the specified data gathering procedures. The competency does not direct itself to the student's ability to design experiments. While this appears to be a perfectly legitimate and viable competency, it does not lend itself to the type of measurement instrument that I have selected. Therefore, I will not address this competency in my study.

**Competency 3 shares some of the same characteristics as competency 6. I will rely heavily upon the judgment of the validation panel in determining whether or not to include this competency in the study. The basic question appears to be whether or not this competency can be effectively measured with a paper and pencil instrument such as the one I have designed.

In order to assist you in your validation task, I have stated each competency and then listed under it the items that I believe measure the indicated knowledge, skill, or performance level. To further expedite your work, I have prepared a "Validation Panel Worksheet." It lists each test item by number and provides a space for you to check "yes" or "no" for your perception of its validity. PLEASE INCLUDE A REASON IN THE "COMMENTS" SECTION WHENEVER YOU CHECK "NO" FOR AN ITEM.

Any additional comments or suggestions are welcomed, but please note that such items as grammar, picture quality, sketch quality, distribution of correct responses, and spacing on pages are still in working draft form. Individual items and the instrument as a whole will be "cleaned up" when the final decision is made as to which items will be retained.

Since I am on a very tight time line, it would be most appreciated if you would return the "Validation Panel Worksheet" (and instrument, if you have made comments on it and/or have no desire to retain it) no later than AUGUST 7, 1981. I have provided a postage paid envelope for your convenience.

Thank you again for your much appreciated help and the generous sharing of your science education expertise.

Sincerely,

Dave

David C. Cox

Enclosures

VALIDATION PANEL WORKSHEET

VALIDATION PANEL WORKSHEET

Panel Number____Date Completed________

REMINDERS:
1. The test items are designed to measure the performance level of students in grades 9 and 10 relative to a set of science process competencies. It is not intended to be a measure of science content knowledge.
2. Please check either the "yes" or "no" space for each test item.
3. If you check "no," please comment as to the reasons for your "not valid" determination. Use the back of the worksheet if more space is needed.
4. The instrument is in "working draft" form, but feel free to make comments or suggestions either in the "comments" section of the "worksheet" or on the instrument itself.
5. If you wish to contact me during the validation process, I can be reached at either (home) or (office).
6. Please return the "worksheet" no later than August 7, 1981.

ITEM NUMBER	VALID YES	 NO	COMMENTS
1-1			
1-2			
1-3			
1-4			
2-1			
2-2			
2-3			
2-4			
3-1			
3-2			
3-3			
3-4			
3-5			

ITEM NUMBER	VALID		COMMENTS
	YES	NO	
4-1			
4-2			
4-3			
4-4			
5-1			
5-2			
5-3			
5-4			
7-1			
7-2			
7-3			
7-4			
8-1			
8-2			
8-3			
8-4			

APPENDIX E

SCIENCE PROCESS COMPETENCY TEST

SCIENCE PROCESS COMPETENCY TEST

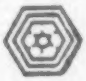
DO NOT OPEN THIS TEST BOOKLET UNTIL YOU ARE TOLD TO DO SO.

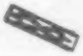
SCIENCE PROCESS COMPETENCY TEST

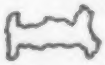
SCIENCE PROCESS COMPETENCY TEST

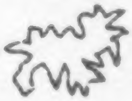
INSTRUCTIONS: This test contains 24 multiple-choice questions. You are to choose the ONE best answer for each question and then darken the space corresponding to it on your answer sheet. If you make a mistake or wish to change an answer, be sure to erase your first mark completely. DO NOT WRITE OR MARK ON THIS TEST BOOKLET. You will have 45 minutes in which to complete the test.

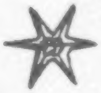
1. Sketches showing the typical shape of 5 of the 10 different types of solid precipitation (snow, graupel, ice pellets, and hail) identified in the International Snow Classification scheme are shown below.

A.  (Plate)

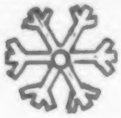
B.  (Column)

C.  (Capped Column)

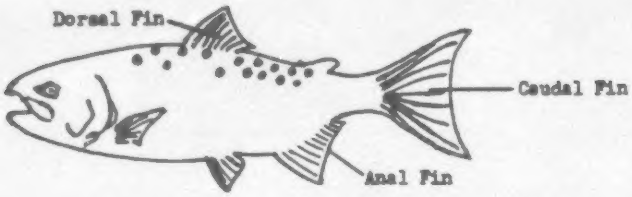
D.  (Spatial Dendrite)

E.  (Stellar Crystal)

The solid precipitation sketched below is most likely a member of which of the types listed above?



2. The fish sketched below is to be identified.


Dorsal Fin
Caudal Fin
Anal Fin

Using the partial classification scheme outlined below, the fish is most likely identified as

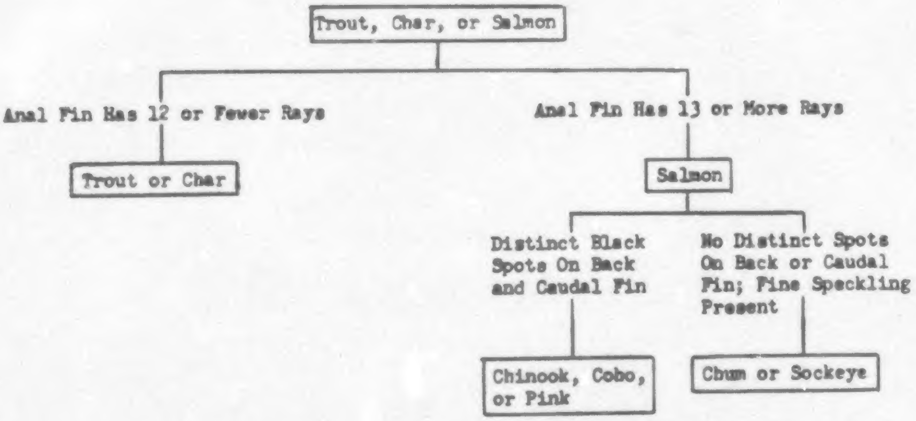
A. Trout or Char

B. Salmon

C. Chinook, Cobo, or Pink

D. Chum or Sockeye

E. Rainbow Trout


Trout, Char, or Salmon
Anal Fin Has 12 or Fewer Rays
Anal Fin Has 13 or More Rays
Trout or Char
Salmon
Distinct Black Spots On Back and Caudal Fin
No Distinct Spots On Back or Caudal Fin; Fine Speckling Present
Chinook, Cobo, or Pink
Chum or Sockeye

3. Several general classes of stars have been identified. The table below provides examples of some of these different types of stars along with some of their important characteristics. (Data from Van Nostrand's Scientific Encyclopedia, Fifth Edition)

Star Type	Example Star	Surface Temp. °K	Luminosity (Relative to the sun)	Density (Relative to water)
White Dwarf	Sirius B	7,500	0.1	27,000
Main Sequence	Sun	6,000	1.0	1.4
Red Giant	Antares	3,100	5,000	0.0000003

If a star has much greater luminosity than the sun and a density much smaller than water, it is probably

A. White Dwarf star

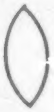
B. Red Giant star

C. Main Sequence star

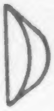
D. Alpha Centauri

E. More data is required in order to obtain an answer

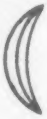
4. Lenses or combinations of lenses are usually classified by shape as shown below.



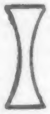
Double Convex



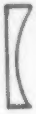
Plano Convex



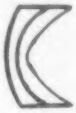
Concavo-Convex



Double Concave



Plano Concave



Convexo-Concave

The combination of 3 lenses sketched below would be classified as which one of the types represented above?

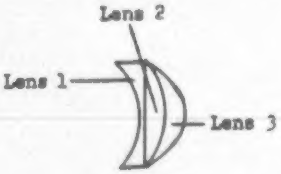
A. Plano Concave

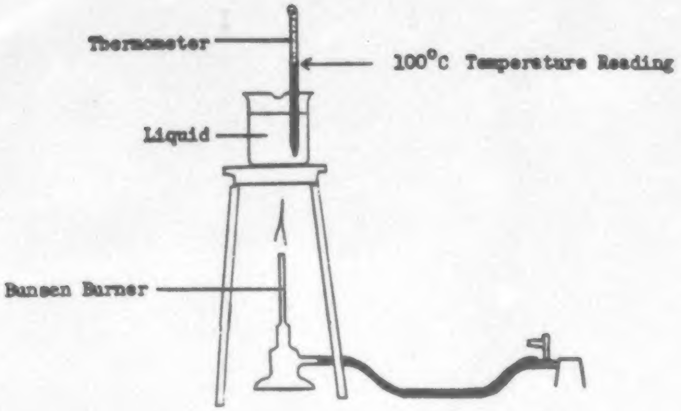
B. Plano Convex

C. Concavo-Convex

D. Convexo-Concave

E. Double Convex




Thermometer
100°C Temperature Reading
Liquid
Bunsen Burner

5. Which one of the following is an observation based upon the laboratory situation depicted above?

   A. Water is boiling

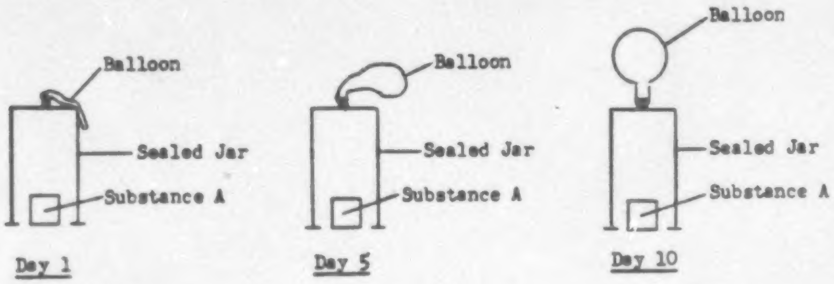
   B. The temperature of the water in the beaker is increasing

   C. The temperature of the substance in the beaker is 100°C

   D. The burner flame has a temperature of 100°C

   E. The liquid in the beaker is superheated

6. A balloon is tightly attached to an opening in the top of a heavy walled glass jar. Sealing wax is placed around the bottom of the jar to prevent air leaks, and the jar is then placed over a sample of substance A. Observations were made over several days, during which the atmospheric pressure and room temperature did not change. The resulting observations are sketched below.


Balloon
Sealed Jar
Substance A
Day 1
Balloon
Sealed Jar
Substance A
Day 5
Balloon
Sealed Jar
Substance A
Day 10

Which statement below represents the best explanation that can be made from the observations?

A. Substance A is giving off a gas

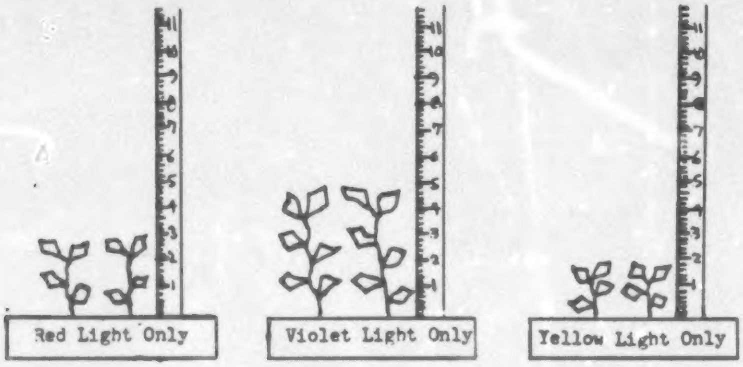
B. The balloon has become inflated

C. Substance A is burning

D. There is a slow leak in the system

E. None of the statements above represents a possible explanation

7. A student conducted an investigation of the effects of 3 different colors of light on the growth of plant X. All of the plants were as close as possible to the same height on Day 1, and all variables except the color of light were held constant. The sketches below represent the situation observed on Day 15.



One can conclude from these observations that during the 15 days

A. Plants grown under yellow light developed fewer leaves

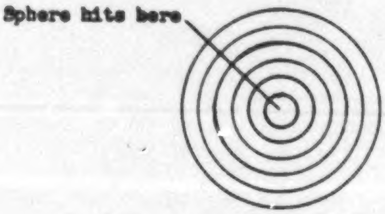
B. Red light prevented the normal growth of plant X

C. Violet light carries more energy than either red or yellow light

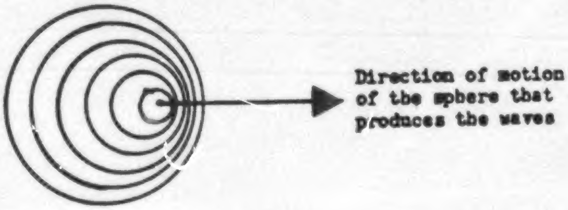
D. The plants grown under yellow light were not as healthy as the plants grown under red and violet light

E. None of the statements above represents a reasonable conclusion based upon the information provided

8. A small plastic sphere is dipped into a tray of water at regular intervals (e.g., it dips into the water every ½ second). The resulting pattern of circular water waves is sketched below.



Now the sphere is moved, while it continues to dip into the water at the same rate. The resulting pattern of water waves is sketched below.



The __best__ description of your __observations__ is

A. No observable change results from the motion of the sphere that is producing the waves

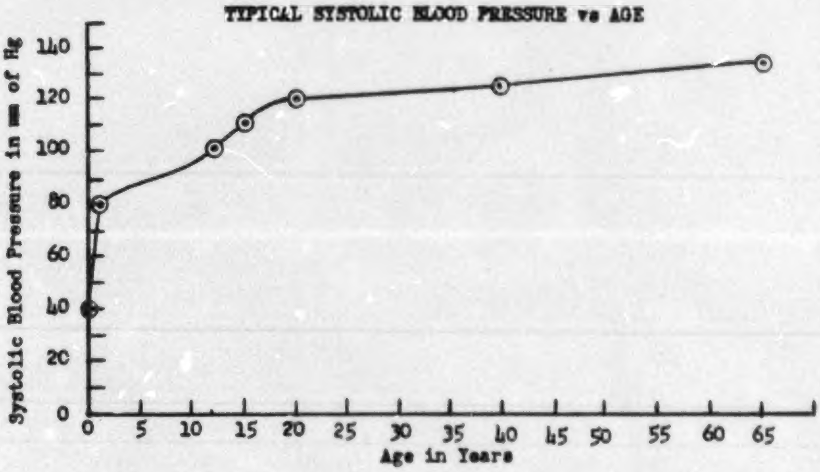
B. The waves are closer together in front of the moving source than behind the moving source

C. The waves are closer together

D. A red shift is observed

E. When the source of the water waves moved, the waves travelled at different speeds

9. Use the graph below in answering this item.



The **best** statement resulting from interpreting the data in the graph above is

A. Systolic blood pressure typically increases with age, with the most rapid increase happening during the first year after birth

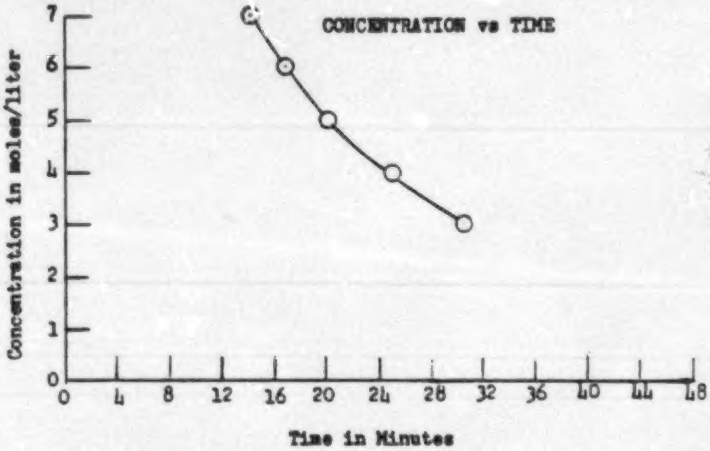
B. Blood pressure typically increases with age

C. Systolic blood pressure typically increases with age

D. The systolic blood pressure typically increases with age at a nearly constant rate

E. Systolic blood pressure typically increases until approximately age 20 and then stays constant

10. The graph below shows the data gathered when some students were observing how the concentration of a solution changed with time. All other variables were held constant.



The best interpretation of the data as it is displayed in this graph is

A. Concentration decreases as time increases

B. Concentration is directly proportional to time

C. Concentration increases as time increases

D. Concentration remains constant

E. There is no apparent relationship between concentration and time

11. Using the graph contained in problem 10 above, predict the concentration when the time is 40 minutes.

A. 3.0 moles/liter

B. 2.0 moles/liter

C. 0.5 moles/liter

D. 0.0 moles/liter

E. 4.0 moles/liter

12. Sunspot activity between the years 1900 and 1960 reached a maximum during each of the following years:

    1906
    1912
    1918
    1924
    1930
    1935
    1941
    1947
    1953
    1959

    Based upon the data given, when is the next (after 1980) maximum sunspot activity likely to occur?

    A. 2000

    B. 1987

    C. 1982 or 1983

    D. 1984 or 1985

    E. 1985 or 1986

13. A group of students are going to conduct an experiment to determine the relationship, if any, between the amount of a particular type of fertiliser used and the resulting crop yield. All other important variables are going to be controlled. Which one of the following is an experimental variable?

    A. The amount of fertiliser used on each experimental plot

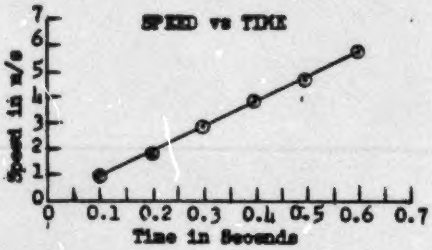
    B. The type of fertiliser used on each experimental plot

    C. The amount of land used for each experimental plot

    D. The amount of water applied to each experimental plot

    E. None of the items listed above are variables during the experiment

14. Speed and time data were recorded while observing a 1-kg mass, starting from rest, fall through a total distance of 2 meters. A graph containing the speed and time data is shown below.



Which one item from the list below was an experimental variable during the time the data were being gathered in the situation described above?

A. Mass of the falling object

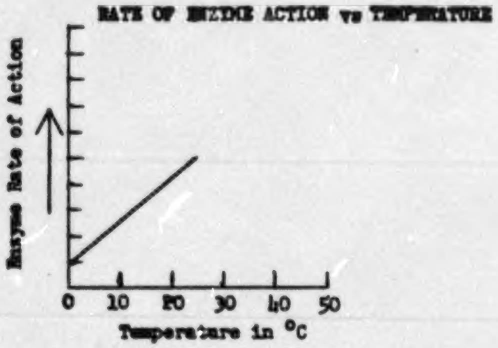
B. Starting speed of the falling object

C. Volume of the falling object

D. Total distance moved by the falling object

E. Time the object had been falling

15. The graph below contains information about the relationship between rate of enzyme action and temperature when pH and concentrations are held constant.



If the temperature is held constant at 25°C, it can be predicted that the enzyme reaction rate will most likely

A. Continue to increase at the same rate

B. Decrease

C. Drop to zero

D. Remain constant

E. Increase, but at a slower rate

16. The chart below shows the temperature change a person feels due to wind (sometimes called the "chill factor") when the wind-free temperature of the air is 15.6°C.

Wind Speed kilometers/hour	Temperature Change °C
0	0
8.0	-2.3
16.1	-5.6
24.0	-6.7
32.0	-7.8
40.1	-8.9

Based upon the data above, what can the temperature change be predicted to be if the wind speed were increased to 48.1 kilometers/hour?

A. 0°C

B. -1.1°C

C. -16.9°C

D. -15.6°C

E. -10.0°C

17. Which of the following is the best example of a scientific model?

A. A human skeleton

B. A labeled cutaway diagram of the earth

C. A small working steam engine

D. A computer

E. All of the examples above are equally good examples of scientific models

18. An outdated scientific model portrayed electricity as composed of positive and negative fluids. Something that was electrically neutral (no charge) had equal amounts of both types of fluid. Which one of the following is a testable prediction based upon this model?

    A. Electricity can only exist on earth

    B. An object with a positive charge will be heavier than an object with an equal amount of negative charge

    C. Electricity can only flow from positive to negative objects

    D. A neutral object that is given a positive charge will gain mass (weight)

    E. None of the statements above are testable predictions based upon the model given

19. Scientific models can be used to do all but one of the following. Which one is not an appropriate use of scientific models?

    A. Make predictions

    B. Provide explanations

    C. Answer questions

    D. Prove scientifically that something is true

    E. Suggest topics or questions for scientific research

20. Which of the following is not explained by use of a scientific model?

    A. The structure of atoms

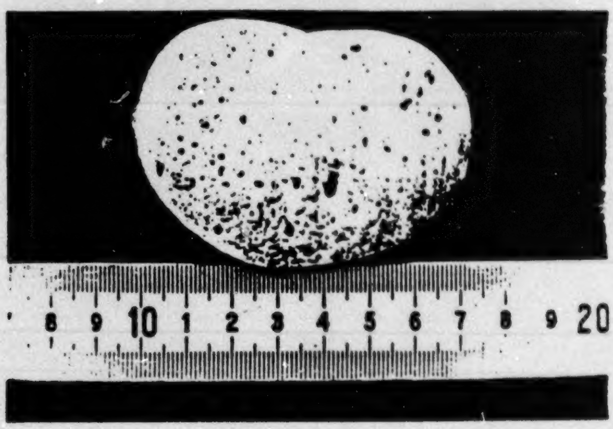
    B. Human thinking processes

    C. Energy formation in stars

    D. Evaporation of water

    E. All of the items above are explained by using scientific models

21. The picture below shows a meter stick being used to measure the length of a rock sample.



The best estimate of the length of the rock sample is

A. 10.0 cm

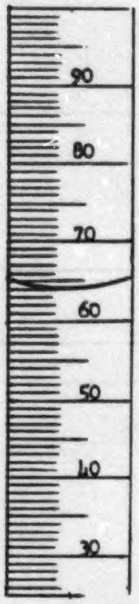
B. 7.30 cm

C. 10.7 m

D. 17.30 cm

E. 107.3 mm

22. A student is using a 100 ml graduated cylinder to measure the volume of a liquid sample. The sketch below shows a portion of that graduated cylinder.



The best estimate of the volume of the liquid in liters is

A. 64.0 liters

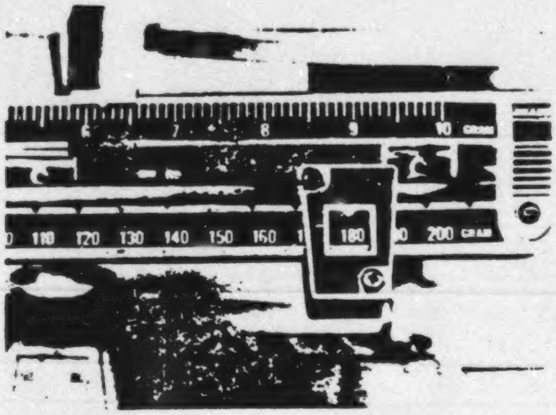
B. 0.655 liters

C. 6.50 liters

D. 0.0640 liters

E. 0.0655 liters

23. The mass of a bone is being determined by using a laboratory balance. The picture below was taken when it was time to read the mass from the balance.


6
7
8
9
10 GRAM
110
120
130
140
150
160
180
200 GRAM

The best estimate of the mass of the bone in kilograms is

A. 180.0 kg

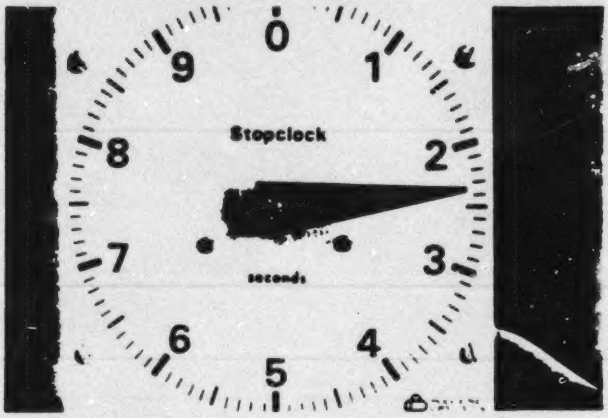
B. 186.0 kg

C. 0.18619 kg

D. 1.8619 kg

E. 6.19 kg

24. A stopclock was used to measure the time required for a pendulum to complete one swing. The picture below shows the reading on the stopclock.


0
1
2
3
4
5
6
7
8
9
Stopclock
seconds

The best estimate of the time required for one swing of the pendulum is

A. 2.7 s

B. 23.5 s

C. 2.35 s

D. 123.5 s

E. 12.35 s

APPENDIX F

STUDENT MATERIALS AND QUESTIONNAIRES

1. Student Information Sheet (SIS)
2. Student Answer Sheet
3. Questions Appended to the Science Process Competency Test
4. Student Information Sheet II (SIS II)
5. Student Information Sheet III (SIS III)
6. Sample Two Letter of Notification

STUDENT INFORMATION SHEET

STUDENT INFORMATION SHEET

NAME____
(last) (first) (middle initial)

SEX M F

GRADE 9 10 11 12

BIRTH DATE__________________________
(month) (day) (year)

SCHOOL Clackamas Milwaukie Rex Putnam

SCIENCE CLASS___________________________________

PERIOD 1 2 3 4 5 6 7

TEACHER____

HAVE YOU COMPLETED ANY OTHER HIGH SCHOOL SCIENCE CLASSES? Yes No

IF THE ANSWER TO THE QUESTION ABOVE IS "YES," PLEASE LIST ALL OF THE HIGH SCHOOL SCIENCE COURSES THAT YOU HAVE COMPLETED.

____

____

PLEASE WRITE THE NAME OF THE LAST MATHEMATICS COURSE THAT YOU COMPLETED.

____

JUNIOR HIGH SCHOOL ATTENDED_____________________________

WERE YOU IN A SCIENCE CLASS IN GRADE 7? Yes All Year Part of Year No

WERE YOU IN A SCIENCE CLASS IN GRADE 8? Yes All Year Part of Year No

PLEASE DO NOT MARK OR WRITE IN THE SPACE BELOW

____

____

____

____

____

____

STUDENT ANSWER SHEET

SCIENCE PROCESS TEST ANSWER SHEET

PLEASE DO NOT WRITE IN THIS SPACE

_ _ _ _ X X X X X X X _ _ _ _ X 0 _ _ _ _ _ _ _

_ _

_ _

_ _ _ _ _ _ _ 1 _ _ _ _ _ _ _ _ _ _ _ _ _ _ X

MARK YOUR ANSWERS IN THE SPACES BELOW

	a	b	c	d	e		a	b	c	d	e
1.	0	0	0	0	0	14.	0	0	0	0	0
2.	0	0	0	0	0	15.	0	0	0	0	0
3.	0	0	0	0	0	16.	0	0	0	0	0
4.	0	0	0	0	0	17.	0	0	0	0	0
5.	0	0	0	0	0	18.	0	0	0	0	0
6.	0	0	0	0	0	19.	0	0	0	0	0
7.	0	0	0	0	0	20.	0	0	0	0	0
8.	0	0	0	0	0	21.	0	0	0	0	0
9.	0	0	0	0	0	22.	0	0	0	0	0
10.	0	0	0	0	0	23	0	0	0	0	0
11.	0	0	0	0	0	24.	0	0	0	0	0
12.	0	0	0	0	0						
13.	0	0	0	0	0						

_ 1

ID:______________________
(First letter of last name) (Birth date)

QUESTIONS APPENDED TO THE SCIENCE PROCESS COMPETENCY TEST

25. Do you feel that you learned any science in school THIS YEAR OUTSIDE OF YOUR SCIENCE CLASS that helped you answer any of the questions on this test?

    Please circle your response. YES NO

    If you answered YES, please indicate where: ____________________

    ____

26. Do you feel that you learned any science OUTSIDE OF SCHOOL THIS YEAR that helped you answer any of the questions on this test?

    Please circle your response. YES NO

    If you answered YES, please indicate where by circling one or more of the items below:

    TV READING OMSI MOVIES OTHER (Please list): _

    ____

STUDENT INFORMATION SHEET II

STUDENT INFORMATION SHEET II

1. **NAME:** ______________________________________
   (last) (first) (middle initial)

2. **SCHOOL:** Clackamas Milwaukie Rex Putnam

3. **BIRTH DATE:** ______________________
   (month) (day) (year)

4. **SEX:** M F

5. **GRADE:** 9 10 11 12

6. **PLEASE LIST ALL OF YOUR HIGH SCHOOL (9-12) SCIENCE COURSES IN THE ORDER THAT YOU COMPLETED THEM, INCLUDING COURSES TAKEN THIS YEAR:**

YEAR IN SCHOOL COURSE NAME(S) TEACHER(S)

----

9 10 11 12 ______________________________________

9 10 11 12 ______________________________________

9 10 11 12 ______________________________________

9 10 11 12 ______________________________________

(IF YOU REQUIRE MORE SPACE, PLEASE USE THE BACK OF THIS SHEET.)

7. **PLEASE LIST ALL OF YOUR HIGH SCHOOL (9-12) MATHEMATICS COURSES IN THE ORDER THAT YOU COMPLETED THEM, INCLUDING COURSES TAKEN THIS YEAR:**

YEAR IN SCHOOL COURSE NAME(S)

----

9 10 11 12 ______________________________________

9 10 11 12 ______________________________________

9 10 11 12 ______________________________________

9 10 11 12 ______________________________________

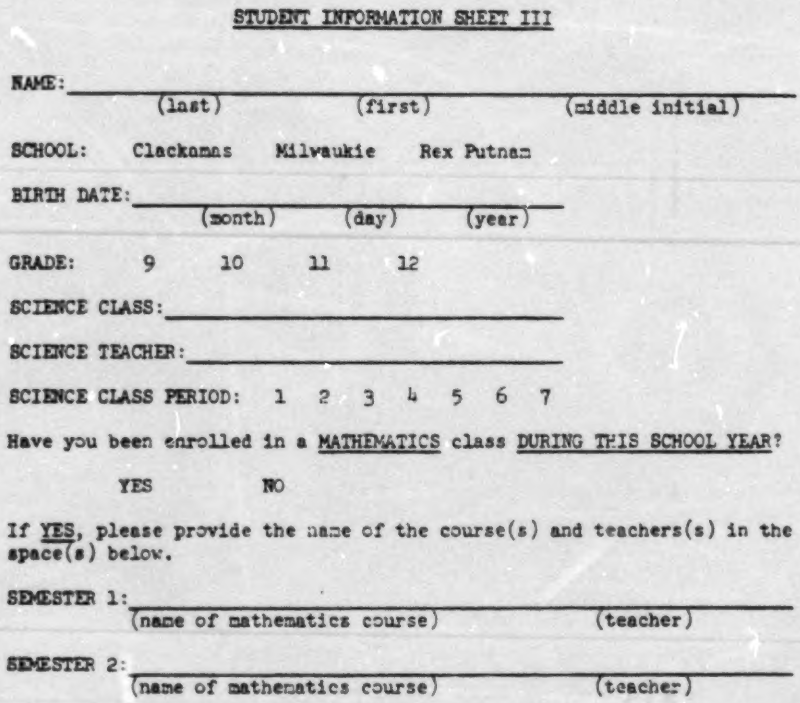
(IF YOU REQUIRE MORE SPACE, PLEASE USE THE BACK OF THIS SHEET.)

8. **JUNIOR HIGH SCHOOL ATTENDED:** Lakes McLoughlin Milwaukie Rowe Other
   (If you attended more than one junior high, circle your eighth grade school.)

9. **JUNIOR HIGH SCHOOL SCIENCE:** GRADE 7 Yes No ?
   If Yes, All Year Part of Year ?
   GRADE 8 Yes No ?
   If Yes, All Year Part of Year ?

10. **SCIENCE LEARNED OUTSIDE SCIENCE CLASSES:**
    AT SCHOOL Yes No If Yes, where? ______________________
    OUTSIDE SCHOOL Yes No If Yes, where? TV Reading OMSI Movies
    Other (please specify) ______________________

STUDENT INFORMATION SHEET III



STUDENT INFORMATION SHEET III

NAME: ______________________________
(last) (first) (middle initial)

SCHOOL: Clackamas Milwaukie Rex Putnam

BIRTH DATE: ______________________________
(month) (day) (year)

GRADE: 9 10 11 12

SCIENCE CLASS: ______________________________

SCIENCE TEACHER: ______________________________

SCIENCE CLASS PERIOD: 1 2 3 4 5 6 7

Have you been enrolled in a MATHEMATICS class DURING THIS SCHOOL YEAR?

YES NO

If YES, please provide the name of the course(s) and teachers(s) in the space(s) below.

SEMESTER 1: ______________________________
(name of mathematics course) (teacher)

SEMESTER 2: ______________________________
(name of mathematics course) (teacher)

SAMPLE TWO LETTER OF NOTIFICATION

May 12, 1982

Dear

You are one of a small group of Rex Putnam High School students selected to participate in one portion of a study of the North Clackamas School District's high school science program. All that will be required from you can easily be completed during one class period. The time that has been selected is PERIOD 1 on TUESDAY, MAY 18, 1982. You have already been pre-excused from your scheduled first period class on that day and should report directly to the AUDITORIUM, where regular attendance will be taken.

Since the number of students involved is small, your valuable input is extremely important. Your participation in this activity will have no effect on your grade in any class, and your anonymity is guaranteed. If you have any questions, please check with Mrs. Winthers.

I certainly hope that you are excited about being one of the group of people chosen to participate in this portion of the study. I am looking forward to seeing you during first period on May 18.

David C. Cox
Project Director

APPENDIX G

VARIABLE LIST

VARIABLE LIST

ABBREVIATION	VARIABLE
ADVBIO1	One semester of elective Advanced Biology
ADVBIO2	One year of elective Advanced Biology
ADVCHEM1	One semester of elective Advanced Chemistry
ADVCHEM2	One year of elective Advanced Chemistry
ADVPH1	One semester of elective Advanced Physics
AGE	Age to nearest one-tenth year
ALG	First year of algebra
AMT7SC1	Full year of science in grade seven
AMT7SC2	Less than one full year of science in grade seven
AMT8SC1	Full year of science in grade eight
AMT8SC2	Less than one full year of science in grade eight
ATSCHOOL	Science learned at school outside of science class
BIO1	One semester of elective Biology
BIO2	One year of elective Biology
BYNDALG	Mathematics after first-year algebra
CATFALL	CAT administered during September through November
CATGR7-CATGR11	Grade level (7-11) when CAT administered
CATLANG	CAT total Language standard score
CATMATH	CAT total Mathematics standard score
CATREAD	CAT total Reading standard score
CATSPRNG	CAT administered during March through May
CATWINTR	CAT administered during December through February
CHEM1	One semester of elective Chemistry
CHEM2	One year of elective Chemistry
CLACKHI	Clackamas High School
CLASSIFY	Sample One pretest and Sample Two score for SPCT Classifying Subtest
CREATE	One or more created CAT scores
ELECSCI	One or more semesters of elective science
ES1	One semester of elective Earth and Space Science
ES2	One year of elective Earth and Space Science

GENMTH	General mathematics
GRADE9-GRADE12	Grade level during 1981-82 school year
GR7SCI	Science in grade seven
GR8SCI	Science in grade eight
ID	School
INTERP	Sample One pretest and Sample Two score for SPCT Interpreting Data Subtest
ITEM1-ITEM24	Correct responses to SPCT items for Sample One pretest and Sample Two
ITEM1A-ITEM24E	Incorrect responses to SPCT items for Sample One pretest and Sample Two
JH1-JH4	Junior high schools in the North Clackamas School District
JH5	Junior high schools outside the North Clackamas School District
MEASURE	Sample One pretest and Sample Two score for SPCT Measuring Subtest
MILHI	Milwaukie High School
MODEL	Sample One pretest and Sample Two score for SPCT Modeling Subtest
MOVIES	Science learned outside of school from motion pictures
NATSC1	One semester of elective Natural Science
NATSC2	One year of elective Natural Science
OBSERVE	Sample One pretest and Sample Two score for SPCT Observing Subtest
OMSI	Science learned at the Oregon Museum of Science and Industry
OTHER	Science learned outside of school from sources other than television, reading, OMSI, or movies
OTHER1	Laboratory assistant and/or science Reading and Conference
OTHER2	Science class completed outside of the North Clackamas School District
OUTSIDE	Science learned outside of school
PERIOD1-PERIOD7	Sample One science class period
PHY1	One semester of elective Physics
PHY2	One year of elective Physics
PHYSC1	One semester of elective Physical Science
PHYSC2	One year of elective Physical Science
PITEM1-PITEM24	Correct responses to SPCT items for Sample One posttest

PITEM1A-PITEM24E	Incorrect responses to SPCT items for Sample One posttest
POSTTEST	SPCT posttest
PPROCOMP	SPCT posttest score for Sample One
PREMATH1	General mathematics
PREMATH2	First-year algebra
PREMATH3	Mathematics beyond algebra
PRESCI1	Natural Science
PRESCI2	Chemistry
PRESCI3	Physics
PRESCI4	Biology
PRESCI5	General Science
PRESCI6	Astronomy
PRESCI7	Physical Science
PRESCI8	Earth Science
PRESCI9	Electronics
PRESCI10	Earth and Space Science
PRESCI11	Integrated Science
PRESCI12	Science Concepts
PRESCI13	Modern Science
PRETEST	SPCT pretest
PRETESTL	SPCT pretest completed late
PRETESTM	SPCT Pretest made up
PREVSCI	Previous high school science
PROCOMP	SPCT pretest score for Sample One and Sample Two
PTCLASS	Sample One posttest score for SPCT Classifying Subtest
PTINTERP	Sample One posttest score for SPCT Interpreting Data Subtest
PTMEASR	Sample One posttest score for SPCT Measuring Subtest
PTMODEL	Sample One posttest score for SPCT Modeling Subtest
PTOBSV	Sample One posttest score for SPCT Observing Subtest
PTSTLATE	SPCT posttest completed late
PTVAR	Sample One posttest score for SPCT Identifying Variables Subtest
PUTHI	Rex Putnam High School
READ	Science learned outside of school by reading
SCISEM1	One semester of elective Science Seminar
SCISEM2	One year of elective Science Seminar
SEX	Gender
SMELSC1-SMELSC10	Semesters (1-10) of elective science

TEACH1-TEACH4	First-Level science teachers at Clackamas High School
TEACH5-TEACH8	First-level science teachers at Milwaukie High School
TEACH9-TEACH12	First-level science teachers at Rex Putnam High School
TV	Science learned outside of school by television
TYPESC1	First-level Biology
TYPESC2	First-level Earth and Space Science
TYPESC3	First-level Physical Science
TYPESC4	First-level Unified and Integrated Science
US1	One semester of elective Integrated Science
US2	One year of elective Integrated Science
VARIABLE	Sample One pretest and Sample Two score for SPCT Identifying Variables Subtest
YRREM1	One year removed from required science
YRREM2	Two years removed from required science
YRREM3	Three years removed from required science

APPENDIX H

UNIFIED SCIENCE EDUCATION

UNIFIED SCIENCE EDUCATION

Unified science education, as it is perceived by contemporary science educators active in its development and evolution, is a highly desirable approach to teaching science for general education purposes. Unified science instructional materials are organized around themes appropriate for viewing the scientific enterprise as a unified way of developing and using knowledge. Due to this frame of reference, the approach either completely eliminates or dramatically minimizes the boundaries that are associated with the traditional discipline-oriented instructional structures.

Organizational themes that have been found to be especially useful in unified science education are major science concepts, the science process skills, natural phenomena, and problems, especially those of the science in society type. The major concepts and science process skills that are most valued in unified science education are those that are the most pervasive in the various science disciplines. Typical of such major concepts would be cycle, equilibrium, force, and field. Among examples of the science process skills would be observing, interpreting data, classifying, and inferring. Numerous examples of such fundamental concepts and basic process skills have been identified by Showalter et al. (1974).

Lindsay (1970) has also provided examples of appropriate science concepts and investigative skills.

Some unified science developers operationally define "concept" in a different manner. The unifying concepts of these curriculum developers are closer to the conceptual scheme category of statement such as those found in Theory into Action . . . in Science Curriculum Development (National Science Teachers Association Curriculum Committee 1964). An example of this category of unifying concept would be "changes in the structural organization are accompanied by changes in energy." (Ward et al. 1969, p. 138). The reference just cited provides a description of a unified science course designed around five of these types of unifying concepts.

The learning activities within unified science units are drawn from many different science disciplines, and in particular from existing discipline-oriented instructional programs. Another emphasis in unified science courses is to consistently provide a variety of learning modes, many of which involve concrete experiences. An enumeration of the characteristics of exemplary unified science instructional materials has been developed by Showalter et al. (1973).

Contemporary statements of the rationale underlying the unified science approach have been rather widely published (e.g., Burkman 1972; Hurd 1973; Showalter 1975; and Cox 1980), with perhaps the most comprehensive statement to date provided by Showalter (1978a). The reader particularly interested in the rationale underlying the unified science approach is directed to these references. Comment here will be restricted to only brief references to some of the major components of the rationale.

The pervasive central element of the arguments for using the unified science approach is that this instructional organization has a particular appropriateness for promoting the development of high levels of scientific literacy for general education purposes. Another dominant theme is that the unified science approach provides an organizational structure that readily lends itself to enhancing the locally relevancy of the science instruction. In addition, the unified science approach provides the opportunity to easily incorporate science--society interface topics such as energy production and use or food additives into the science curriculum.

A significant contributor to the development of the unified science approach has been the Federation for Unified Science Education (FUSE). FUSE was founded by eight science educators active in unified science curriculum development in 1966 (Federation for Unified Science Education 1966). The organization has published two newsletters. The Federation for Unified Science Education Bulletin was published from 1966 through 1971 and Prism II from 1972 until 1976. FUSE organized and sponsored frequent conferences, presented workshops, and served as an information clearinghouse.

Funding from the National Science Foundation (NSF) enabled FUSE to establish a national Center for Unified Science Education (CUSE) in 1972. (Prism II 1972). CUSE was located at The Ohio State

University in Columbus, Ohio, through its funded lifetime. The FUSE Center for Unified Science education is currently located at Capital University in Columbus, Ohio.

The unified science approach appears now to be generally accepted as a viable alternative to the more traditional science programs and courses that have been used to address the science education dimension of general education. This is evidenced not only by the apparently increasing number of unified science programs in schools throughout the nation, but by references to the approach in the literature. The early references frequently refered to unified science programs as "experimental" (American Association for the Advancement of Science 1969, p. 1) or "curriculum innovations" (Troost 1968, p. 845). The more recent literature appears to take a "state of the art" point of view (e.g., National Association of Secondary School Principals 1972; Fiasca 1975; and McNeil 1981). McNeil (1981, pp. 61-63) has identified integrated studies, citing the unified science approach as an example, as one of three current trends in the academic subject curriculum.

Unified Science Courses and Programs

The approach to science teaching known as unified science education established its American roots in the late 1950's. The first clearly recognizable effort to create a complete high school level unified science program occured at The Ohio State University School, beginning in 1959 (Showalter 1964). This four-year program also served as the focus for two of the earliest formal studies of the effects of unified science instruction on students. Slesnick (1967) examined the comparative effectiveness of unified science instruction and contemporary "traditional" science instruction in enabling students to achieve a "rational image of the universe." Slesnick concluded, with qualifications, that the unified science students had in fact developed a more "inclusive" rational image of the universe. Richardson and Showalter (1967) investigated the possible long term effects of high school unified science experiences on interest in science, scientific literacy, and preparation for college science. Findings indicated a general and consistent favorability, although not always significant at the stated minimum level, for the unified science students.

As had been the case for The Ohio State University School, the unified science materials developed by local school groups have for the most part been those to report the most positive responses in the classroom. This local development, perhaps more accurately described as eclectic unit assembly, enables the materials to address directly the science education goals, objectives, and needs of the local community while taking into account the nature of the learners and the unique operational constraints (e.g., length of class periods, facilities, equipment, staff qualifications) and resources (e.g., nearby natural phenomena, staff strengths, community business and industry) of the educational setting. In summary, locally designed and assembled unified science instructional materials are personalized and customized for the target staff, students, and community.

Integrated science

Much of the early activity in the high school level unified science education arena consisted of the development and implementation of what are now referred to as integrated science courses. These courses and programs, for the most part, restructured into multiple-year sequences the typical content of existing chemistry, physics, and biology courses. The most obvious advantages of such arrangements were elimination of unnecessary redundancy, logical content development, and operational validation of the interrelatedness of the incorporated science disciplines. A rather comprehensive rationale for course development of this type has been articulated by Fiasca (1970).

Among these early integrated science courses were two-year physics-chemistry sequences developed in Portland, Oregon (Fiasca 1969), Millburn, New Jersey (Blessing 1969), and Newark, New Jersey (Lerner 1964). A two-year physics-chemistry-biology program was developed in St. Louis, Missouri (Bixby 1969). The science staff at Monona Grove High School, Wisconsin, developed and implemented a four-year integrated program (Pfeiffer 1969). The two-year sequences developed in Portland, Oregon, and Millburn, New Jersey, soon evolved into three-year integrated chemistry-physics-biology programs (Cox 1975; and Blessing 1969).

Several of the early projects developed materials that were in the interface between integrated and unified science. Among these were a one-year ninth-grade course in Cupertino, California (Montag 1965), a two-year program at the University of Chicago Laboratory School (Klopfer 1966), and junior high school programs in Michigan (VanDeventer 1968) and Florida (Bethune 1969).

Unified science

The locally developed unified science programs of the 1970's displayed the pervasive diversity that has become a trademark of the approach. This program diversity is a reflection of the wide variety of perceived science education goals, valued instructional strategies, and unique educational resources and constraints that exist in secondary schools throughout the nation. The most clearly emerging trends during the decade of the 70's were the increased number of course development projects at grades nine and ten, many of which have highest emphasis on development of the science process skills, and the movement towards some form of semi-individualized instruction. Exemplars of the diversity within unified science programs span the nation and encompass schools of a wide variety of types.

The lower form of the Matteo Ricci College Unified Science program in Seattle, Washington, is a three-year program for grades 9-11. The first year of the sequence uses the instructional materials developed for the initial year of the Portland Project course. Years two and three are locally developed materials of the modular unit type. The modular unit format (Center for Unified Science

Science Education 1975) is a semi-individualized format.

Towards Humanization and Individualization of Science (THIS) is a three-year individualized unified science program designed for use in grades 10 through 12. It was developed at Moline, Illinois, Senior High School, but has been used at a number of different schools (Bushman and Goar 1976). The instructional materials consist of approximately 250 modules, each one of which consists of rationale, objectives, sample evaluation, commentary, learning activities, and a list of resources. A great variety of module mix and match possibilities exist, since there is no designated sequence.

The first year of science at Rex Putnam High School in Milwaukie, Oregon, is a unified science course whose instructional implementation is somewhat traditional. It features a science process skill orientation with a high percentage of student directed hands on activity, which encompasses about 85 percent of the classroom time. The course consists of 12 locally developed units averaging 3 weeks each. The student materials are bound in three-ring binders to form the student "text." This course is the unified science course included in this study. A detailed description of the course and the mechanics of its development has been prepared by Cox (1979).

A kindergarten through grade 12 unified science program was implemented in approximately one hundred schools in Anne Arundel County, Maryland (Fertitta 1975). The program is self-paced until about age 15, where semester length high school courses become available.

The science staff at P.K. Yonge Laboratory School at the University of Florida have developed a three-year Correlated Science Program (Gadsden et al. 1975) for the high school years. This self-paced unified science program is built around six major concepts (e.g., equilibrium, models). In addition, P.K. Yonge offers a one-year Aviology course, which uses the phenomenon of flight as its unifying theme for the study of science.

The Unified Science Education for Rochester, New York, program consists of three 10-unit courses for use in grades 9 through 11. These modular unit materials were developed cooperatively by the Rochester City School District and the Diocese of Rochester, starting in 1976. (City School District of Rochester 1977).

Not all high school level unified science curriculum development has been restricted to a single school or school district. Two larger scale projects have also undertaken the task. The Educational Research Council of America (ERCA) Science Department developed a unified science program consisting of a number of flexible format units designed for use in secondary school science. The largest unified science project to date, however, is the Individualized Science Instructional System (ISIS) undertaking. ISIS is anchored around a number of minicourses (e.g., Heart Attack, Household Energy, Buying and Selling), each of which requires about three weeks of class time. These commercially produced materials are promoted and used nationally.